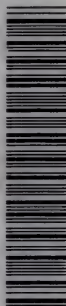


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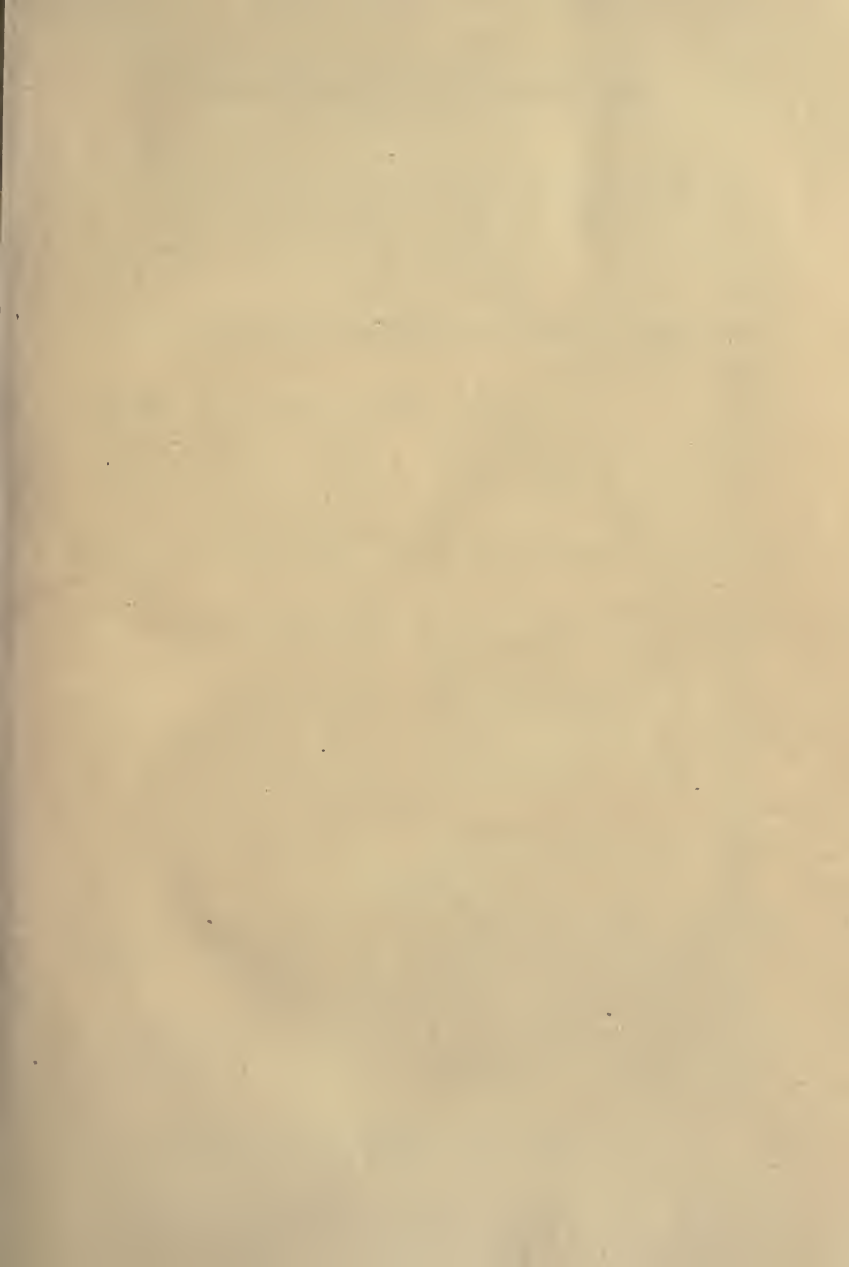


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The Students' Quiz Series.

PHYSIOLOGY.

A MANUAL FOR STUDENTS AND PRACTITIONERS.

BY

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PREFACE.

THE present book is a brief summary of the salient features of Human Physiology. It is not intended to compete with nor to take the place of the more elaborate text-books. The idea has been to present the subject in such a manner as to fix in the memory facts already learned in less limited treatises.

There is no claim of originality for this book. It is practically and of necessity an abstract of standard works, and principally of those of Dalton, Foster, and Kirke. The arrangement has, in a general way, been made to conform with that of the last-named authority. The cuts are many of them from Dalton's *Physiology*. Doubtful questions have often been referred to Foster, whose *Text-book of Physiology* is the reference-book of a large proportion of the schools. Some of the histological descriptions are derived from Prudden's *Practical Normal Histology*.

NEW YORK.

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PHYSIOLOGY.

GENERAL CONSIDERATIONS AND PROXIMATE PRINCIPLES.

Define human physiology.

HUMAN PHYSIOLOGY is that branch of biology which refers to the functions and properties of the organs in the living human body.

In entering upon the study of the functions of organs it becomes desirable to understand something of the nature of the fundamental elements of living tissue which we call cells.

What are cells?

Cells may be described as nucleated masses of protoplasm of microscopic size, usually possessing limiting membranes known as cell-walls, and capable of passing through the changes which are characteristic of life and death. Some cells do not possess a nucleus, but this is quite exceptional. More commonly each cell has a nucleus or more than one, and in many instances there is a nucleolus within the body of the nucleus.

What is protoplasm?

Protoplasm is an unstable albuminoid substance of more or less gelatinous nature. Its reactions are those of albumin (coagulation by heat and mineral acids), and its chemical composition is of varying proportions of the elements C, H, N, O, S. Protoplasm is living albumin or proteid.

Illustrate the life of the cells by the amœba.

The characteristic changes through which cells pass are well illustrated by the amœba: (*a*) The power of spontaneous movement, in which a small portion of the cell is first advanced, and

then the whole cell seems to flow to and into its branch. (b) Motion in response to various physical and chemical stimuli. (c) The power of taking food, absorbing portions and rejecting the rest. (d) Reproduction of its kind. This is accomplished by splitting of the cell into two, each with its own nucleus and life-history. (e) Death, in which the constituent elements undergo chemical changes. All cells follow more or less closely this cycle of changes by which we differentiate living matter from unorganized substances.

Name some of the kinds of cells found in man.

Epithelial, connective-tissue, blood-, and nerve-cells.

What is epithelium ?

The name "epithelium" is given to the cells which cover the skin, mucous and serous membranes of the body, and also enter into the formation of the glands. Its varieties are—(1) *Simple*, a layer of flat (squamous), cubical, (spheroidal), or cylindrical (columnar) cells, as in the serous and mucous surfaces; (2) *stratified*, when it occurs in layers, as in the skin; (3) *transitional*, where it has the characteristics of both in situations where the other two forms approach one another, as in the ureters. (4) In the glands are found *functional cells*, which partake of the character of the epithelium of the surface. They are arranged in groups about the ducts. Such cells are often known as secreting or glandular epithelial cells.

What is ciliated epithelium ?

The simple epithelium possesses hair-like processes in certain locations, and this is known as *ciliated epithelium*. The hairs are endowed with motion, and wave in such manner as to throw forward small particles which fall upon them.

Name the chief uses of epithelium.

Protection, as skin, serous surfaces; motion, ciliated epithelium of air-passages and Fallopian tubes; secretion, in glands—*e. g.* gastric juice; sensation, in the cones of the retina, olfactory cells of nose, etc.

What is endothelium ?

It is a simple form of squamous or scale-like, flat epithelial cells which line the serous membranes and the blood-vessels. The cells

are very delicate, and are not stratified. They are of various forms, usually irregularly polygonal, and are joined at the edges so as to form a sort of mosaic.

What are connective tissues?

They are the structures which form the frame and supports of the body and of the organs of the body. The ligaments, tendons, fasciæ, cartilage, and bones are examples of them. The fibrous connective-tissue cells are found in all organs in greater or less amount. In the organs whose use is the support of the body or one of its members these cells predominate. In other organs the fibrous cells serve to hold in place the functional cells and to maintain the shape of the organs.

What are the proximate principles of the body?

They are the substances entering into the composition of the body, and are inorganic and organic.

What are the inorganic elements?

Chemically, C, H, O, N make up a very large portion of the body-weight, water alone (H_2O) forming about three-fourths of the total. Besides these, sodium, potassium, lime, and magnesium, in chemical combinations with sulphur, phosphorus, chlorine, and carbon (sulphates, phosphates, chlorides, and carbonates), are found in considerable amounts, and less abundantly iron, silica, and fluorine. Occasionally minute quantities of some of the other metallic elements—arsenic, lead, copper, and manganese—are found.

How are the organic proximate principles classified?

(1) Nitrogenous, and (2) non-nitrogenous.

(1) The former take the principal part in the formation of solid constituents of the body, and occur in all the body tissues and fluids. They make up the protoplasm of cells and essential ingredients of the fluids, both circulatory and excretory. Chemically, they are compounds of C, H, O, N, sometimes with sulphur or phosphorus.

(2) The latter (non-nitrogenous) class of bodies are made up of the fats and carbohydrates.

What is the reaction of the fluids of the body?

Alkaline, with only four notable exceptions. These are—gastric juice, perspiration, vaginal mucus, and acid urine.

NITROGENOUS ORGANIC BODIES.

Proteids.	1. Native albumins found in nature,	{ Egg albumin, Serum albumin, Globulin, Paraglobulin, Fibrinogen, Myosin, Vitellin, Globin,	{ Soluble in water and coagulable by heat.
	2. Globulins found in nature,	{	{ Soluble in sol. NaCl, 1 per cent.; coagulable by heat; nearly all precipitated by alcohol.
	3. Derived albumins, derived from Class 1 by action of acids, alkalis, or ferments,	{ Acid albumin, Alkali albumin, Casein,	{ Soluble in weak (1 per cent.) HCl sol.; not coagulable by heat; precipitated by neutralizing solution.
	4. Fibrin, from Class 1 by action of "fibrin ferment,"	{ Fibrin,	{ Insoluble in cold HCl (1 per cent.) sol., but soluble at 60° C.
	5. Coagulated albumin, by heat, etc., from Class 1,	{ Coagulated albumin,	{ Soluble in gastric juice, becoming peptones, and also in strong acids, becoming acid albumin.
	6. Peptones, by action of digestive ferments on Class 1,	{ Peptones,	{ Very soluble in water; not precipitated by heat, acids, alkalis, or alcohol. Peculiar in dialyzing freely.
Gelatin.	{ Gelatin, soluble in hot water.		
	{ Mucin, soluble in weak alkaline solutions.		
	{ Elastin, insoluble.		
Products of the decomposition of nitrogenous matter.	{ Chondrin, soluble in hot water.		
	{ Keratin, insoluble; probably a complex compound.		
	{ Crystallizable acids— <i>e. g.</i> glycine, leucine, taurine, etc.		
Nitrogenous, but of uncertain composition.	{ Urea and its allies— <i>e. g.</i> creatine, uric acid, xanthine, etc.		
	{ Pigments— <i>e. g.</i> bile-pigments, melanin, hematin, etc.		
	{ Ferments— <i>e. g.</i> amylolytic, proteolytic, milk-curdling, etc.		
	{		

NON-NITROGENOUS ORGANIC BODIES.

Fats.	<div> <div> <div> <div>Olein, liquid at ordinary temperatures.</div> <div>Palmatin, solid " "</div> <div>Stearin, " "</div> </div> <div> <div>(melts at 113° F.)</div> <div>" "</div> <div>(140° F.)</div> </div> <div> <div>United in fatty tissues.</div> </div> </div> </div> <div> <div>Insoluble in water.</div> <div>Soluble in ether.</div> <div>" " chloroform.</div> <div>" " hot water.</div> <div>Saponify.</div> </div>
	Cholesterin, chemically an alcohol, but closely allied to the fats.
Carbohydrates.	<div> <div> <div> <div>Starch, soluble in hot water, not in cold.</div> <div>Glycogen, soluble in cold water.</div> <div>Dextrin, " " "</div> </div> <div> <div>Not found in unchanged state in body, except as food.</div> <div>Not found in body except as food.</div> <div>Derived from saccharose and starch by ferment action.</div> </div> </div> </div> <div> <div>Found in milk.</div> <div>From starch by ferments, ptyalin.</div> <div>Found in muscles and in heart.</div> </div> <div> <div>Iodine test (blue color).</div> <div>Iodine test (red color).</div> <div>All respond more or less readily to fermentation and copper tests.</div> <div>Non-fermentable with yeast.</div> </div>
Fatty acids.	<div> <div> <div>Formic acid.</div> <div>Acetic " "</div> <div>Lactic " "</div> </div> <div> <div>Found only in perspiration.</div> <div>" " "</div> <div>" " muscle-plasma.</div> </div> </div>

THE BLOOD.

What is blood?

Blood, while circulating in the body, is a somewhat viscid, opaque fluid, of a red color; this color varies in different parts of the body from a brilliant scarlet to a deep purple or nearly black color. It consists of a nearly colorless liquid (plasma or liquor sanguinis), in which swim the blood-corpuscles or globules.

What are the physical characteristics of blood?

It has a specific gravity at 60° F. (15° C.) of 1055 (1045–1062); a faintly alkaline (potassium phosphate) reaction; temperature about 100° F. (37.8° C.); a salty taste; and an odor which is characteristic, and often peculiar to the animal from which it is taken. When taken from the body it tends to form a clot or coagulum (crassamentum).

What is the quantity of the blood?

About one-twelfth of the body-weight, and is distributed as follows in round numbers:

About one-fourth in heart, lungs, and large vessels;

“ “ in liver;

“ “ in muscles;

“ “ in other organs.

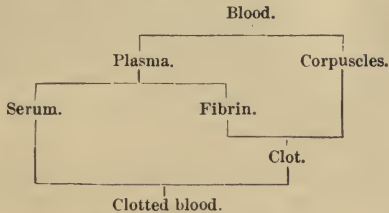
Describe the formation of a clot.

If blood be drawn into a shallow vessel and exposed to the air, it will become semisolid at the surface in two or three minutes. This jelly-like condition will extend to the sides of the vessel, and then throughout the entire mass, so that if the vessel be inverted the blood will not flow at the end of ten or fifteen minutes. Then drops of pale fluid (serum) begin to appear at the surface, and these unite to form an amount of fluid sufficient in an hour to float the clot, which meanwhile is contracting from the sides of the vessel. The serum continues to exude and the clot to contract for twenty-four to thirty-six hours. The color of the clot remains red, while the serum has a pale straw color.

Why does blood clot?

Clotting is due to the formation of a substance called *fibrin*, which appears as a mesh of fine fibrils and soon entangles the corpuscles. This mesh of fibrin contracts and squeezes out the

watery elements of the blood to form serum, and holds the solid components, as shown by diagram as follows :



What is the source of the fibrin ?

Largely, if not entirely, from the plasma. A substance known as *plasmine* is obtained from plasma by saturation with salt, without which there is no formation of fibrin ; and this substance redissolved readily clots and forms fibrin. Plasmine may be imitated by uniting solutions of *fibrinogen* and *paraglobulin*, obtained from plasma. A third element is considered probable, and this is known as the fibrin ferment: it is probably derived from the colorless blood-corpuscles. There is some reason for the belief that paraglobulin is not an active factor in forming fibrin, but that it may unite with and render inert some substance (unknown) which prevents the formation of fibrin in the conditions of life.

Mention some conditions which affect the coagulation of blood.

Hasten.

- Moderate warmth, 100°-120° F.
- Contact with foreign matters.
- Access of air.
- Rest.
- Addition of moderate amounts of water.

Retard or prevent.

- Greater heat or extreme cold retard or entirely check.
- Contact with living tissues, especially blood-vessels.
- Absence of air retards. After death by asphyxia blood remains fluid ; also when air is withheld from drawn blood, as by film of oil.
- Agitation of vessel retards.
- More than twice the bulk of water.
- Addition of viscid substances—*e. g.* glycerin, syrup.
- Addition of neutral salts, about 2 per cent. solution.
- Digestive ferments.
- Strong acids or alkalies.

Why does not blood clot in the living vessels?

The reason is not clearly understood, but it is supposed that the living blood-vessels exert a restraining influence upon the formation of the fibrin ferment. The formation of a clot may occur in a vessel after injury of the lining by ligation, by the introduction of a foreign substance, or by disease of the vessel. This fact is made apparent in the ligation of vessels, in the treatment of aneurism, and in the formation of emboli.

What are the principal forms of blood-corpuscles?

The red or colored, and white or colorless. They make up nearly half (40–45 per cent.) of the total weight of fluid blood. The proportion of the red to the white is about 500 to 1.

Describe the red blood-corpuscles.

Human colored blood-corpuscles are circular, biconcave disks with rounded edges; in diameter they are about $\frac{1}{3500}$ in., in thickness about $\frac{1}{12000}$ in. In water they swell and become flat or convex. When seen singly they appear yellow, but their color is red when seen in groups. Microscopic examination shows that they have no nucleus and no limiting membrane (which defects preclude the name "cell"); but they have an elastic framework or stroma, which retains an individuality for each corpuscle, and allows changes of shape to adapt them for capillary circulation, and brings them back to the original form after such distortion.

Why are they red?

Because the stroma of each corpuscle is infiltrated with a red coloring matter, *hæmoglobin*.

Mention some other peculiarities of red cells.

(1) Blood-corpuscles (sp. gr. 1088) are somewhat heavier than plasma (sp. gr. 1030), and therefore tend to sink when drawn in a vessel. In blood that coagulates slowly the corpuscles have an opportunity to do this, and the result is a formation of fibrin at the surface of the clot. This surface is of a light yellowish color, and is known as the "buffy coat."

(2) The red corpuscles in the process of clot-formation form in rolls or columns like piles of coins, the corpuscles adhering to one another at the edges, and the columns so formed adhere to one another by their ends, so as to make clusters.

Are the red corpuscles the same in man as in the animals?

In mammals the general character of the corpuscles is the same as in man, but the size of the corpuscles varies in different animals. In reptiles, fishes, and birds the red corpuscles are oval, nucleated, and usually are larger than those of mammals.

What are microcytes?

In many specimens of blood are observed some corpuscles which are smaller than the rest: they are called *microcytes*, and are probably immature corpuscles. One form is of especial interest. They are of about one-third the size of ordinary corpuscles, not deeply pigmented, round or oval. They are called the *blood-plates* of Bizzozero, and have been affirmed to be broken up to form the fibrin ferment.

What is the origin of the colored corpuscles?

This is somewhat uncertain, but it is probable that red corpuscles take their origin from colorless nucleated corpuscles similar to if not identical with white corpuscles; possibly also from the nuclei of white globules, from the tissue of the spleen, and from the marrow of the bones.

How are the red corpuscles destroyed?

Without doubt, the red corpuscles have a definite life, and when their work is done die as do the other parts of the body, after a tolerably definite existence. Neither the length of their life nor the manner of their death is definitely understood. It is believed, and partially demonstrated, that they undergo disintegration in the spleen.

What is the number of the red blood-corpuscles?

It is almost beyond estimate, but it is calculated that the average for normal human blood is about 5,000,000 in each cubic millimetre. In practice it is customary to estimate the number of red corpuscles by counting the corpuscles in a minute but measured quantity of blood spread upon a ruled microscope slide. Such an instrument is known as a hæmocytometer, and that of Gowers is frequently used.

Describe the white or colorless blood-corpuscles.

They are spherical, granular masses of protoplasm, possessing a nucleus, but no cell-wall. They are about $\frac{1}{2500}$ in. in diameter, though some appear smaller, and are probably undeveloped white corpuscles.

By what other name are they known ?

Leucocytes.

What is their proportion, numerically, to the red corpuscles ?

The proportion is 1 to 500 or 600, but this relation is varied by conditions of health and disease, by age, etc., being more abundant in youth, in anæmic conditions, in pregnancy, and after a full meal.

What power is peculiar to white corpuscles ?

The power of amœboid movement, by which they are able to pass through the walls of capillaries into the surrounding tissues. This we call *diapedesis*. The physiological value of this is not known.

What is the source of the white corpuscles ?

Leucocytes come, no doubt, from the lymph-glands, in which they may be seen in large numbers—"lymph-corpuscles"—and from which they are poured into the blood. They also originate by fission. Some also, probably, are derived from the spleen and from the thymus gland, perhaps also from microcytes.

What is the ending of the leucocytes ?

Many, probably, are decomposed in the blood-vessels, but more end as colored cells ; still others take part in inflammatory processes and are ended in this way.

What are the uses of the blood ?

(1) To receive and convey food and oxygen to all the parts of the body.

(2) To receive from the organs and carry away the refuse matters to other organs whose function is to excrete them.

(3) To warm and moisten all parts of the body.

What is the active ingredient of the blood in its oxygen-carrying function ?

Hæmoglobin. In the lungs the hæmoglobin of the red corpuscles is combined in loose chemical union with oxygen, and this union is broken down in the tissues of the body.

What is the difference between arterial and venous blood ?

(1) Arterial blood is bright red (scarlet) from the combination of hæmoglobin with oxygen (oxy-hæmoglobin) ; and venous blood is purplish or blue from deoxidation of the oxy-hæmoglobin.

(2) Arterial blood coagulates somewhat more quickly.

(3) Arterial blood contains more oxygen and less carbon dioxide than venous.

What is the chemical basis of blood ?

Water is the principal constituent, and in it are dissolved salts and proteid matters, and suspended in it are the corpuscles. Roughly, the composition of blood may be tabulated as follows :

<i>Serum.</i>		<i>Corpuscles.</i>	
Water	90	Water	69
Proteids	8	Inorganic salts (chiefly sodium chloride and potassium phosphate),	1
Salts	1	Organic matter,	30
Fats, }	1	(Hæmoglobin 27	
Glucose, }		Proteids 2.7	
Extractives, }		Fats 0.3)	
Pigment, }			
	100		100

What are the gases of the blood ?

Carbonic oxide, oxygen, and nitrogen. The proportion of gases to the blood is about one-half the volume. Of these, carbonic oxide is greatly in excess in both arterial and venous blood. The proportion is shown in the tabular form, thus :

Arterial blood, per 100 volumes, CO₂ 39, O₂ 20, N 1+.
 Venous blood, per 100 volumes, CO₂ 46, O₂ 10, N 1+.

CIRCULATION OF THE BLOOD.

What is meant by the circulation of the blood ?

The course which the blood, as a transporting medium, follows in taking food and air to the tissues and bringing away the used-up material for excretion, returning when freshly charged with oxygen and food.

Of what does the circulatory apparatus consist ?

- (1) The heart, which propels the blood ;
- (2) The arteries, which convey it from the heart to the different parts of the body ;
- (3) The capillaries, a network of inosculating tubules interwoven with the substance of the tissues and bringing the blood into intimate contact with it ;
- (4) The veins, which collect the blood from the capillaries and return it the heart.

FIG. 1.



Describe the course of the blood in circulation, beginning with its entrance into the left auricle.

Into the left auricle from pulmonary veins, thence passing the open mitral valve into the left ventricle (Fig. 1). Upon contraction of the ventricle the mitral valve is closed and the aortic valve thrown open, so that the blood is thrown into the aorta, and thence through the systemic arterial circulation into capillaries and on into veins, the systemic veins finally joining to fill the venæ cavæ, and from them the right auricle. From the right auricle past the tricuspid valve into the right ventricle, whence it is thrown through the pulmonary artery (guarded by the pulmonary semi-lunar valve) into the pulmonary capillaries, and thence into the pulmonary veins, whence it started. Thus we have in reality two circulations, the systemic and pulmonary.

Describe the heart.

The heart is a muscular organ situated in the thorax, where it lies between the lungs within the pericardial sac, and rests upon the diaphragm somewhat to the left of the mid-line of the body. It is conical in form, and is so suspended by the great vessels that the apex points to the left and downward. Its size is about that of the closed fist (weight, in adults, about 10 ounces).

Diagram of the Circulation: 1, heart; 2, lungs; 3, head and upper extremities; 4, spleen; 5, intestine; 6, kidney; 7, lower extremities; 8, liver.

What are its cavities?

It is divided by a septum into two cavities, not connected, the right and left (Fig. 2). Each of these in turn is subdivided into two parts, the auricle and the ventricle. The auricles are thin-walled cavities, whose function is to receive the blood from the veins and pour it into the ventricles. The ventricles are the most powerful portions of the heart-muscle, the left being much stronger and thicker than the right ventricle.

FIG. 2.

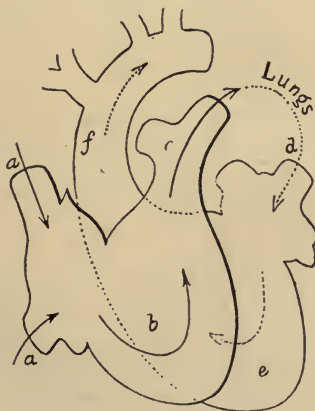


Transverse Section of the Bullock's Heart in the State of Cadaveric Rigidity: *a*, cavity of the left ventricle; *b*, cavity of the right ventricle.

What is the capacity of these cavities?

Auricles, about 4 oz. ; ventricles, about 6 oz.

FIG. 3.



Course of Blood through the Heart: *a, a*, vena cava, superior and inferior; *b*, right ventricle; *c*, pulmonary artery; *d*, pulmonary vein; *e*, left ventricle; *f*, aorta.

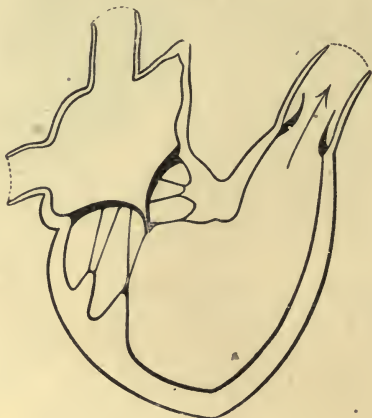
What is the use of the valves?

To allow the blood to pass in one direction only through the heart (Fig. 4).

Describe the structure of the arteries.

They are surrounded by a dense fibrous coat externally, and lined internally by a smooth serous (endothelial) lining; between

FIG. 4.



Valves of the Heart.

these is an elastic layer of fibrous tissue, which has interlaced in its structure muscle-cells. Each artery has its own *vasa vasorum*, or nutrient vessels, and is usually enmeshed in a plexus of sympathetic nerves, "vaso-motor nerves."

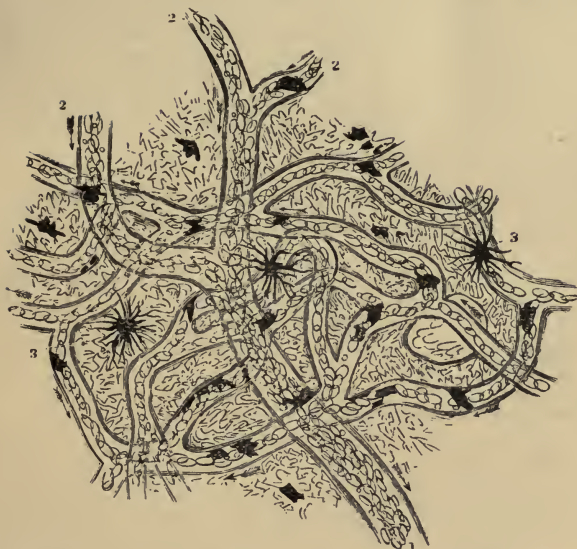
Describe the capillaries.

The capillary blood-vessels are channels of very small but variable size, but usually of about sufficient calibre to just permit the passage of the red and white corpuscles. They are usually composed of a single layer of endothelial cells joined at the edges, though near the arteries and veins there is sometimes an elastic-fibrous coat. A sympathetic nerve-plexus surrounds these vessels. The capillaries form a complicated network in the tissues, and the mesh of the net varies in shape and size greatly with the vascularity and function of the tissue.

Describe the characteristics of the veins.

In structure the veins are similar to the arteries, but much less

FIG. 5.



Capillary Plexus in a Portion of the Web of a Frog's Foot (magnified 110 diameters): 1, trunk of vein; 2, 2, 2, its branches; 3, 3, pigment-cells.

firm and elastic; veins collapse, while arteries remain open when not distended by blood. Valves occur in most of the veins; these are so placed as to prevent the blood from tending to flow backward. The valves are so placed as to aid the onward progress of the blood in the veins, the pressure of neighboring muscles forcing forward the blood, which cannot regurgitate past the valves.

What is the relative area of arteries, capillaries, and veins?

With the division of the arteries into branches the sectional area of the branches is greater than of the stem. Of the veins the same is true, while the total sectional area of the capillary system is much greater than of either. For purposes of simile the comparison may be made of two funnels placed base to base. In numbers one may consider the sectional area of aorta as 1; of venæ cavæ, 2 or 3; of capillaries, (about) 800.

Describe the action of the auricles.

During the period of rest of the heart blood flows freely from the veins into the ventricles, the auriculo-ventricular valves offering no resistance; but the influx is so strong that by the time the heart begins to contract the auricle is quite filled and the ventricle partially. The contraction of the auricle is sudden and very quick, commencing at the great veins and extending toward the ventricular opening. Both auricles contract simultaneously.

Why does not the auricle throw the blood back into veins?

(1) The power of the auricular contraction is not sufficient to cause a reflux.

(2) The muscular coat of the great veins near the heart contracts, and helps to prevent this regurgitation.

(3) The weight of the incoming blood opposes.

(4) Valves in the veins oppose, and the Eustachian valve guards the inferior vena cava.

Describe the action of the ventricles.

The ventricle is distended during its period of rest by the flow of the blood from the veins and by the auricular contraction; and its contraction seems continuous with that of the auricle, so immediately does it succeed. The ventricular contraction is slower, and probably completely empties the cavity. The ventricles contract simultaneously. The shape of the ventricles is changed: as the heart-muscle becomes hard and rigid in contraction, the section of its base becomes circular instead of elliptical, as it is during repose; the ventricles shorten and twist to the right, and the form is conical. As the organ relaxes, it turns back to its former position and shape, that of a cone with elliptical base. This shortening of the ventricles in contraction is compensated by the lengthening of the great vessels at the base as they become distended by the load of blood.*

What are the functions of the valves of the heart?

In considering the functions of the valves of the heart one must bear in mind constantly that the organ is a pump whose office is to force the blood in one direction. There are four principal valves—two auriculo-ventricular, and two in the great arteries, the aorta and the pulmonary artery. (1) As the ventricle fills, the *auriculo-ventricular* valves are floated up from the sides of

* Some physiologists deny the shortening of the ventricles in systole.

the ventricle in such manner that their edges are in contact, cusp to cusp. As the ventricle contracts more violently, pressure is brought to bear upon the valve, so that not only is the edge in contact, but also portions of the surfaces of the cusps. These valves are of considerable area, and are guyed in position by the *chordæ tendineæ*, which spring from the papillary muscles, so that eversion of the valve into the auricle is impossible. (2) The *semilunar valves* form a guard against the return of blood to the ventricle at the pulmonary and aortic openings of the ventricles. These valves are forced open by the ventricular contraction, and through them the blood rushes to distend the elastic walls of the large arteries. The pressure of the blood under this elastic grasp is sufficient to throw the cusps of the valves into action. The corpora Arantii are useful in making a perfect closure of the valve, though not absolutely essential. A part of the weight of this pressure is borne by the thick ventricular wall, from the outer edge of which the artery springs, while the valves are attached to the inner edge.

What is meant by the safety-valve action of the tricuspid valve?

Under some circumstances the tricuspid valve does not entirely close, but allows a certain amount of regurgitation of blood. This is in conditions of disease or of violent exertion, in which the lung capillaries are overcharged with blood. This leakage of the valve is conservative, by relieving the pressure upon the delicate capillaries of the alveolæ. Pulsation in the jugular veins indicates this regurgitation. The condition is not pathological, and with altered conditions disappears.

What terms are used to describe the alternate contraction and relaxation of the heart?

Systole, a contraction; diastole, a relaxation.

What is meant by the period of repose?

Between the contractions of the heart-muscle there is a perceptible pause, which has been called the period of repose. If the time of a cycle be divided into five parts, the systole of auricles will employ 1 part; systole of ventricles, 2 parts; period of repose, 2 parts. The accuracy of this division is not absolute, for, whatever the pulse-rate, the ventricular systole consumes nearly four-tenths of a second.

Describe the heart-sounds.

The first sound is heard best over the apex of the heart. It is of a dull, prolonged, booming character. The second sound is heard immediately after the first, and is a sharp, quick, almost clicking sound; it is heard most clearly over the base. The sounds are said to somewhat resemble that expressed by *lubb-dŭp*.

What is the cause of the heart-sounds?

The origin of the first sound of the heart is not fully explained; but as it is synchronous with the ventricular systole and with the closure of the auriculo-ventricular valves, it is supposed to be due to muscular action and vibration of auriculo-ventricular valves and chordæ tendineæ. The second sound is synchronous with the closure of the semilunar valves, and is caused by this action.

What is the normal frequency of the heart's action?

At birth,	about	130	per minute.
At three years,	"	100	" "
In adult life,	"	75	" "
In old age,	"	65	" "

This rate is varied from time to time by conditions of bodily health and by environment. The heart in women is somewhat more rapid than in men. After eating, during exercise, in a hot or rarefied atmosphere the heart is more rapid. The relative frequency of heart and respiratory action is about three or four heart-beats to one respiratory act.

What force does the heart exert in systole?

The left ventricle exerts more than twice as much power as the right. The exact intraventricular pressure in man has not been ascertained. The expansion of the heart exerts a negative (or suction) pressure, which aids the onflow of the blood, especially from the lungs to the left ventricle. The intra-auricular pressure is very much less than the intraventricular, and there is a negative pressure during diastole in the auricles.

What is the estimated work of the heart in systole?

Estimated in foot-pounds, each ventricular contraction represents $3\frac{1}{2}$ to $4\frac{1}{2}$ foot-pounds. In twenty-four hours this is estimated to equal more than 120 foot-tons. In another light, if the blood is one-twelfth of the body-weight, and if the amount of blood pumped with each ventricular contraction is 6 oz., in an ordinary man an

amount of blood equal to the total blood of the body will pass through the heart in about half a minute.

What are influences of the nervous system upon the heart's action?

This matter is somewhat undecided at the present, for the reason that many of the results must be obtained from experiments upon the hearts of cold-blooded animals. We do know that the mechanism of rhythmical contraction is contained within the heart itself. Nerve-ganglia are demonstrated in the frog's heart which are essential to its action; presumably similar ganglia exist in the human heart. These ganglia are connected with fibres from the pneumogastric (or vagus) nerve and with the sympathetic system.

What is the effect of the pneumogastric nerve upon the heart?

It has an *inhibitory* or slowing effect upon the heart; for if we cut the nerve the heart becomes more rapid, and if we stimulate the *peripheral* end of the nerve we slow the heart again. This action may be traced to the medulla oblongata, where a cardio-inhibitory centre is located.

What is the relation of the heart to the sympathetic nervous system?

Certain fibres of the sympathetic from the cervical and upper dorsal spinal cord pass to the heart. If these fibres are left after all other nerve-connections of the heart are cut away, stimulation of the spinal cord will cause the heart to become rapid. These are known as *accelerator nerves*.

What is meant by the pulse?

The wave which is felt in an artery after the systole of the ventricle.

What is a sphygmograph?

An instrument used to trace mechanically a diagram of the pulse-wave.

How is the heart nourished?

By the coronary arteries, which arise in the sinuses of Valsalva behind the leaves of the semilunar valve. They do not receive blood during systole, but during diastole from the pressure of blood in the elastic arteries. The blood is returned to the right auricle through the coronary vein.

What causes unite to compel the return of the blood through the veins?

(1) *Vis a tergo*, or the pressure remaining from the force of the left ventricular systole and arterial elasticity.

(2) *Muscular action* in pressing upon the veins which have valves.

(3) *Suction Power of the Heart*.—During diastole the opening of the heart-cavity is sufficiently strong to exert a rather strong “negative pressure” or suction power.

(4) Aspiration (or suction) power of the chest in respiration.

(5) The slight rhythmical contractions of the veins.

What is meant by vital capillary force?

The capillaries are not unchanging blood-channels, but may be seen to dilate and contract under the influence of stimuli. We have seen that each capillary has its accompanying vaso-motor sympathetic plexus; and this it is which controls this force, seen in blushing, pallor, etc.

What is arterial tension?

The walls of the arteries being very elastic, and the blood being forced into them at considerable pressure, permits them to keep the blood under elastic compression within the arteries, so that when an artery is cut the blood spurts from it in a jet. The capillaries, though collectively of much greater area than the arteries, by reason of the friction they offer to the blood-stream maintain a less degree of tension.

What causes modify the arterial tension?

(1) The rate of the heart-beats, by keeping the arteries fuller or less full, will modify the blood-pressure in the arteries.

(2) Vaso-motor changes, by increasing or decreasing the friction offered the arterial blood, vary the tension in the arteries.

(3) The amount of blood in the system must to a great extent determine the limits of arterial pressure. In great exsanguination the arterial pressure is quite low.

(4) Motion of the thoracic walls in breathing necessarily changes the arterial tension by the pumping force exerted by this motion.

RESPIRATION.

What constitutes respiration?

By respiration we mean the process by which oxygen is introduced to the system and by which carbonic oxide is excreted.

This function is performed in the lungs, and the transfer is effected by the agency of the blood.

Describe the course of the air in entering the lungs.

Air is taken through the nose or mouth, and passes through the pharynx to the larynx; entering the rima glottidis, it passes through the larynx to the trachea and bronchi. The air is somewhat warmed and moistened in its passage. The trachea and bronchi are lined with ciliated epithelium, which serves to sweep particles of dust and the like out of the air-passages.

Describe roughly the minute anatomy of the lung.

Each lobe of the lung is composed of numerous lobules, to each of which a small bronchiole enters, and the minute terminal branches of these bronchioles (*infundibula*) widen into a sort of irregular funnel having pouched or sacculated dilatations known as air-cells. These air-cells are supported by numerous elastic fibres, and are lined with a very thin layer of flat (not ciliated) epithelium. Outside the epithelial lining is a very close mesh of capillaries, which are often exposed to air on both sides by lying in a partition between two of the air-cells. The air-cells or vesicles are about $\frac{1}{60}$ in. in diameter, and the space between the capillaries is often less than the diameter of a capillary.

What is the blood-supply of the lungs?

There are two sources: (1) from the bronchial arteries (systemic) for nutrition; (2) from pulmonary artery for oxidation.

How is air introduced to the lungs?

The thoracic cavity in which the lungs lie being a closed cavity, the expansions of its walls will tend to create a partial vacuum in its interior. It is by this means that air is introduced. This expansion of the chest-wall (and with it the lung) we call *inspiration*. Contraction of the cavity of the thorax tends to cause compression of its contents, and thus to expel the contained air: this we call *expiration*. The complete act is called *respiration*. ✓

Describe briefly the mechanism of respiration.

A. *Inspiration*.—The diameters of the thoracic cavity are all increased—(1) the vertical by the action of the diaphragm; (2) the lateral and antero-posterior diameters by the elevation of the ribs. Thus we may have a diaphragmatic or abdominal type of breath- ✓

ing and a costal or chest type; the former is characteristic of men, the latter of women.

B. In *expiration* the natural elasticity of the lungs and the chest-wall causes very little muscular action to be needed in natural expiration. In forced expiratory efforts all muscles which depress the ribs may be called into action here.

What is the force of the respiratory effort?

The average man is able to elevate a column of mercury in a manometer tube $2\frac{1}{2}$ to 3 inches by an effort at inspiration. In expiration, when forced, the mercury will range about an inch higher, but it should be remembered that many muscles which are ordinarily used for other purposes may be called into play in this effort.

What is meant by the term "vesicular murmur"?

It is the sound heard in listening over a normal lung during respiration, and is described as a soft sighing sound heard at the instant air enters the alveoli. Its cause is not fully understood, but it is supposed to be due to the friction of the air against the walls of the vesicles.

What is tidal air?

The amount of air which is habitually changed in an ordinary act of breathing. In forced inspiration the excess of air is known as *complemental air*.

What is reserve air?

The air left in the lung after ordinary expiration. After forced expiration there always remains a certain amount of air, known as *residual air*.

What is the respiratory capacity?

The greatest quantity of air which one can drive from the lungs after forced inspiration: this is about 225 cubic in. in an average adult man. The tidal air for the same man will be about 30 cubic in. These figures are not constant, and vary with conditions of health, figure, age, sex, and atmospheric conditions.

What is the normal rapidity of the respiration?

In a healthy adult 14 to 18 per minute. In infants and invalids the rate is often much more rapid. The ratio to the pulse-rate is about 1 to 5 in the healthy individual.

Describe the rhythm of respiration.

The respiratory act is rhythmical, inspiration being slightly more rapid than expiration, a slight pause occurring after expiration before a fresh breath is drawn.

Describe the movements of the nostrils and larynx in respiration.

With every inspiration (especially if rapid) there is dilatation of the nostrils and a partial closure during expiration. The rima glottidis is in the same way opened for the ingress of air. This is like the respiratory act, in that the opening is a muscular act during inspiration, and the recoil elastic in ordinary breathing.

What is the composition of the atmosphere?

It has a nearly uniform composition.

By Volume.

Oxygen, 79 parts.

Nitrogen, 21 "

Carbonic acid, .04.

Ammonia and impurities, trace.

By Weight.

75 parts.

25 "

What is the temperature of expired air?

The expired air is at about the temperature of the body, whatever its temperature when inspired.

How much carbonic acid does exhaled air contain?

While ordinary air contains only about $\frac{1}{2}$ a part of carbonic acid per 1000, expired air is found to contain about 43 parts per 1000 of CO_2 . This is varied by conditions of health and disease, age, atmospheric conditions, and a number of other causes.

How much oxygen is taken from the air in respiration?

The oxygen of the exhaled air is decreased in about the same ratio that its carbonic acid is increased (roughly 5 per cent.). This proportion is not exact, as there is some excess of oxygen which is absorbed in the system and does not reappear as CO_2 .

How much water appears in expired air?

The amount varies with the atmospheric conditions as well as bodily changes, but ordinarily in a day about 10 ounces of water in the form of vapor are found in expired air in excess of that normally present. This may amount to 30 ounces, or fall as low as 6 ounces.

Mention some other changes in the respired air.

Small quantities of organic matter and of ammonia are found.

Has the nitrogen of the air a physiological bearing?

A small amount of this gas is found in the blood, but it is mostly in simple solution, and is not supposed to be of physiological value. In respired air it is of use as a diluent of the oxygen.

Describe the respiratory changes of the air in the lungs.

In the blood oxygen is in loose chemical combination with the hæmoglobin (oxy-hæmoglobin). The amount of the oxygen in the residual air of the pulmonary alveoli is estimated at about 10 per cent., that of expired air being 16 per cent. It is found that unless there is present about 4 per cent. of oxygen there is no tendency for the blood of the pulmonary arteries (venous) to take up fresh oxygen, or the *tension* of the oxygen in the reduced hæmoglobin of venous blood is about 4 per cent., and unless the oxygen tension in the lungs is greater, there is no absorption of oxygen. But, as we have seen, the amount of oxygen amounts to at least 10 per cent., and therefore the excess is sufficient to exceed the demands, and the exchange is readily made by diffusion through the thin capillary walls in the alveoli.

On the other hand, the tension of the carbonic acid in the pulmonary arteries is much higher than in the alveoli, and hence the extrusion of this gas by diffusion is accomplished.

How is the blood changed by respiration?

(1) Color, deep purple to bright scarlet by oxidation of the reduced hæmoglobin—*i. e.* from venous becomes arterial blood; (2) gains oxygen; (3) loses carbonic acid; (4) becomes cooler; (5) coagulates more readily.

Name some of the special actions of modified respiration.

There are a number of involuntary and voluntary special respiratory acts, largely reflex, which are dependent upon modifications of inspiration and expiration—*e. g.* sighing, hiccough, cough, sneezing, speaking, singing, sniffing, sobbing, laughing, yawning.

What is the nervous mechanism of respiration?

In the medulla oblongata are centres for each half of the body, from which arise automatically the rhythmical impulses for the respiratory acts. While these are automatic, they may be stimu-

lated by reflex influence. The nerves which convey to the muscles of inspiration their impulse are the phrenics (to the diaphragm) and the intercostals (to the intercostal muscles). The reflex stimuli are conveyed by the pneumogastric nerve, and are twofold: by the main trunk of the nerve the inspiratory efforts are excited, and by the superior laryngeal branch expiratory reflexes are obtained. Thus stimulation of the superior laryngeal nerve may be said to inhibit the inspiratory centre and to excite the expiratory centre, while the contrary may be said of the main trunk of the nerve.

How is the vagus excited to this reflex activity?

While the respiratory centres seem to act automatically, yet in certain conditions, in which oxygen is wanting in the blood, the absence of oxygen (not the presence of carbonic acid) stimulates the respiratory centres, through the pneumogastric filaments in the lungs, to increased activity. This reflex activity results in forcible respiratory efforts which we call *dyspnœa*. It is not known whether this reflex arises from the absence of oxygen from the air of the alveoli or from the blood of the pulmonary capillaries.

What are the symptoms of lack of oxygen in the blood?

If the need be only moderate, there will be increased effort of both expiration and inspiration, and the respirations will be rapid—a condition known as *hyperpnœa*. As the oxygen becomes less and less abundant the symptoms become more severe, and the condition is known as *dyspnœa*. The *dyspnœa* increasing, the respiratory efforts become very violent, and the condition of *asphyxia* is seen. In this the face is blue, eyes starting, face anxious, and respirations very rapid and strident. Then follows a convulsive condition which is brief, the convulsions being very violent and involving the entire body. After this the patient lapses into a state of exhaustion, in which the respirations are slow, very feeble, and the general condition is one of collapse. Death ensues very soon.

How is air vitiated by lack of ventilation?

In ill-ventilated rooms the air of the room is used repeatedly, and, besides becoming partially deprived of its oxygen, is charged with carbonic acid and with putrescible nitrogenous organic matters. This causes an atmosphere which is intolerable to one who enters from fresh air. That such a condition is unsanitary needs no argument.

What are the requirements for good ventilation?

It is generally accepted as a fact that about 1000 cubic feet of air-space per head must be allowed in sleeping quarters, and sufficient facilities for exchange of air to allow complete change in each hour. This ventilation must be accomplished without exposure to draughts.

What effect has respiration upon the circulation?

Each inspiration causes a partial vacuum in the thoracic cavity, and hence it, so to speak, sucks the blood to the heart from the great veins. Each expiration does not, however, check the flow of blood, for the expiration does not increase the air-pressure, but simply returns to the normal. The inspiration, then, increases arterial tension by facilitating the venous return.

DIGESTION.**What is digestion?**

By this term we indicate the process by which food is introduced to the body and prepared in such way that it becomes suitable for absorption and tissue-nutrition. The process may be divided logically and conveniently into mastication, insalivation, deglutition, stomach digestion, intestinal digestion, and defecation.

Describe mastication.

When a mass of food enters the mouth it is caught by the tongue and moved to a position such that it may be crushed and ground between the upper and lower teeth. This process is favored by the action of the tongue and of the cheeks, which not only crush the softer food-masses, but bring the less tractable portions repeatedly under the action of the teeth.

Describe the teeth.

There are during life two sets of teeth, *temporary* and *permanent*. In the first set are 20 teeth, and in the second 32. The permanent set are arranged as follows:

	Molar.	Bicuspid.	Canine.	Incisor.	Canine.	Bicuspid.	Molar.
<i>Upper.</i>	3	2	1	4	1	2	3
<i>Lower.</i>	3	2	1	4	1	2	3

The tooth-structure resembles bone in anatomical as well as chemical view. The central portion, or *cement*, is true bone, and about it is a somewhat harder layer called *dentine*. Outside of all is a very dense layer of *enamel*.

What muscles are involved in the act of eating?

Biting movements are produced by action of the temporal, masseter, and internal pterygoid muscles, opposing the depressors of the jaw; grinding movements are produced by the alternate action of the external pterygoids. The action is to some extent reflex, though largely voluntary, and is controlled in the medulla through branches of the cranial nerves, motor impulses coming through branches of the trigeminus and (to the tongue) hypoglossal nerves.

What do we mean by the term "insalivation"?

The mixing and thorough moistening of the food-mass with the saliva and mucus in the mouth during the act of chewing is called insalivation.

What is the saliva?

The saliva is derived almost entirely from the parotid, submaxillary, and sublingual glands, and is secreted most abundantly during mastication of food. It is a transparent watery fluid, and is somewhat viscid from the mixture of mucus. This viscosity allows it to retain air-bubbles when churned by the action of the tongue and cheeks. It has a sp. gr. of about 1006 and an alkaline reaction. Chemically, it is mostly ($99\frac{1}{2}$ per cent.) water, holding in solution very small amounts of salts and proteids, with the addition of a ferment called ptyalin. The amount secreted in twenty-four hours is estimated to be 1 to 2 quarts, most abundant secretion occurring during mastication.

What is the use of saliva?

It keeps the mouth in a moist condition, and so lubricates the tongue in speaking and in chewing; dissolves the soluble portions of the food, and in this way brings them in contact with the organs of taste; mixes with the food, and forms a soft and slippery bolus suitable for swallowing. Saliva from the front of the mouth, containing more water, softens the bolus, while the tonsillar and pharyngeal secretions, being mucous, coat it with a slippery surface; and the saliva has a special digestive function by the action of its ferment, ptyalin.

What is the action of ptyalin?

Ptyalin is a ferment (a non-nitrogenous body having an uncertain chemical composition), with the special property of converting cooked starch into grape-sugar. While the ferment itself cannot

be isolated and analyzed, a glycerin solution may be obtained from salivary glands which have been dehydrated by alcohol. This ferment does not act upon any other body than starch. The action of the ferment in changing starch to sugar is known as an amylolytic action, and such a ferment is called an amylolytic ferment. The kind of sugar resulting from the action of ptyalin is grape-sugar or glucose, maltose being found as an intermediate step in the ferment's action.

At what age do the salivary glands become active?

At four to six months; hence the reason for avoiding starchy food for young infants.

What tests are used to determine the presence of sugar and of starch?

For starch an entirely reliable and simple test is that by iodine: a blue color follows the reaction; it is a very delicate test. For sugar Moore's and Fehling's tests depend upon the reduction of a copper solution, and are quite delicate. The fermentation test is of value in accurate quantitative determination of sugar.

What is the action of the nervous system upon the salivary glands?

Saliva is secreted more abundantly upon the application of a stimulus. It is therefore increased by reflex nerve-force. The stimuli may be mechanical or chemical or mental; thus the flow of saliva is increased by taking food into the mouth or by irritating the inside of the mouth by scratching or burning, or by looking at or smelling or even thinking about food.

In the submaxillary gland the chorda tympani nerve is said to have a double function—to increase the vascularity of the gland by one portion of its fibres, and to excite the secreting function by another set of fibres, the sympathetic nerves of the gland acting as the vaso-constrictors.

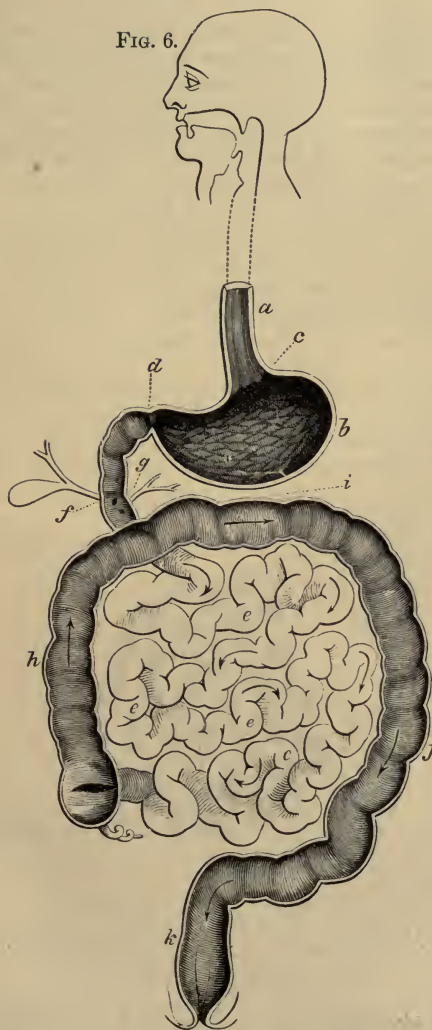
In the parotid the vaso-dilator impulse comes also from the facial nerve through the fifth by the communication of the lesser petrosal nerve. The vaso-constrictor impulse comes from the sympathetic.

There is found a medullary centre which controls this function.

Describe an act of deglutition.

De-glutition, or swallowing, is the process by which we convey food from the mouth to the stomach, and may be divided for the purpose of analysis into three actions: 1st. The food after masti-

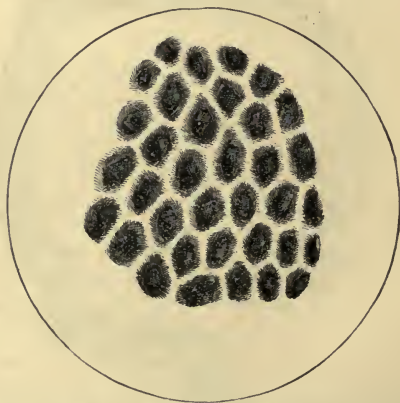
FIG. 6.



Human Alimentary Canal: *a*, œsophagus; *b*, stomach; *c*, cardiac orifice; *d*, pylorus; *e*, small intestine; *f*, biliary duct; *g*, pancreatic duct; *h*, ascending colon; *i*, transverse colon; *j*, descending colon; *k*, rectum.

cation is pushed by the tongue against the palate, and so forced on toward the fauces. 2d. As soon as the bolus enters the pharynx it is pushed on by the tongue and by the contraction of the pillars of the fauces and the constrictors of the pharynx toward the œsophageal opening. The pharyngeal vault is guarded from invasion by solid or liquid food by the valve-action of the soft palate, while the opening of the glottis is protected by the simultaneous intrinsic muscular closure of the rima glottidis and by the valve-like cover of the epiglottis. When the muscles of the fauces and tongue push on the food-mass, they also draw up the larynx and dilate the œsophageal opening. 3d. The œsophagus grasps the food, and a peristaltic wave-series carries it rapidly on to the cardiac opening of the stomach. The beginning (1st) of the act of swallowing is voluntary, the remainder reflex, and is governed by centres in the medulla oblongata acting through the cranial nerves which supply the parts. The trigeminus, glosso-pharyngeus, and vagus by their sensory and motor functions act both in the capacity of afferent and efferent communication with the medullary centre.

Fig. 7.



Free Surface of the Gastric Mucous Membrane, viewed from above, from pig's stomach, cardiac portion, moderately magnified.

Describe the structure and function of the stomach.

The stomach (Fig. 6) is an organ which resembles in structure

the rest of the intestinal tract; it is hollow, having a peritoneal covering and a mucous membrane lining, with a muscular layer between. It is in this mucous membrane that the special function of the stomach lies, for here are found glands which secrete the gastric juice. The active peristaltic motion churns the food about after deglutition, and exposes it thoroughly to the action of the digestive agents. The function of the stomach is the digestion of proteids.

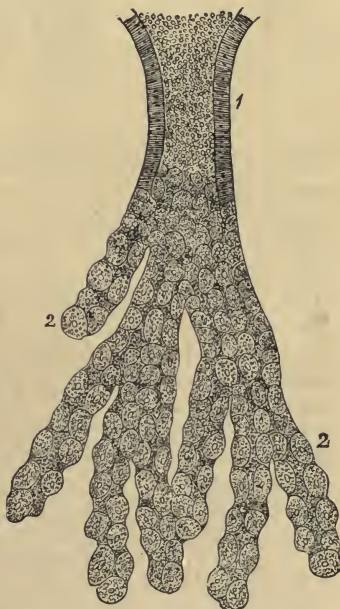
Describe the glands of the stomach.

If one looks closely at the mucous surface of the stomach, it is seen to present a sort of reticulated (Fig. 7) appearance, the meshes being larger at the pyloric than at the cardiac end of the stomach. It is in the interstices of this mesh that the glands open. The openings are smaller at the cardiac than at the pyloric end, and the character of the glands changes: we therefore speak of two varieties of gastric glands—1, peptic; 2, pyloric.

1. The peptic glands are arranged in groups throughout the stomach, but not so abundantly at the pyloric end. They often consist of a simple tube dipping into the surface and lined with columnar epithelium (Fig. 8), but they may be branched—*i. e.* several glands may empty into a common duct. The columnar epithelium in the deeper portion of the gland contains large, almost globular cells, which are known as peptic cells.

2. The pyloric glands, or mucous glands, like the peptic, may be simple or compound. The ducts are larger, and the large cells are wanting (Fig. 9). During digestion the cells of both varieties of glands become swell-

FIG. 8.



Compound Gastric Follicle, from the cardiac portion of the human stomach: 1, excretory tubes leading to the surface; 2, tubercular follicles containing spheroidal cells (Kölliker).

en, and in them are found granules which are supposed to be pepsin or that from which pepsin is formed.

FIG. 9



Tubular Follicles, from pyloric portion of pig's stomach, showing their caecal extremities and epithelial lining: at *a* the torn end of a follicle, showing its cavity more highly magnified.

What is the gastric juice?

When the stomach is not at work it contains no gastric juice, but is bathed in an alkaline mucus. As soon as food enters the organ, however, it immediately begins to secrete considerable quantities of an acid fluid which soaks into and mingles with the food. The celebrated case of Alexis St. Martin, who had a gunshot wound resulting in gastric fistula, enabled Beaumont, surgeon U. S. A., to investigate accurately its composition: It is a limpid, colorless fluid of sp. gr. 1001–1010 and acid reaction. It contains about $\frac{1}{2}$ per cent. solid matter. Its composition is nearly—

Water	99.50
Pepsin25
Hydrochloric acid05
Salts (alkaline chlorides and phosphates)20
	<hr/>
	100.00

This composition is not constant, as the proportions vary considerably, HCl, for example, being present much more abundantly in some cases.

What is the daily secretion of gastric juice ?

From 10 to 20 pints.

What is the source of the hydrochloric acid ?

It is probably secreted by the cubical parietal cells of the peptic glands. Very little seems to be formed by the pyloric glands.

What other acids are found in the stomach ?

Lactic, acetic, butyric, and some other fatty acids. They are products of digestion or of abnormal processes due to decomposition of food.

What is the source of pepsin ?

The globular cells in the peptic glands. These cells are supposed to form a substance called *pepsinogen*, from which pepsin is derived. Pepsin is derived for commercial or for experimental purposes from fresh stomachs by scraping the surface and dissolving out the ferment with cold water, or by mincing the mucous membrane and extracting the ferment with glycerin after dehydrating with alcohol.

What is the function of gastric juice ?

The principal function of the gastric juice is the transforming of proteids into peptones. This action depends upon the presence of both pepsin and acid. The first change which occurs is the formation of acid albumin, but as the action of the ferment continues the acid albumin is transformed to peptone. The presence of acid albumin is demonstrated by the addition of an alkali, which precipitates it.

What are the characteristics of peptone ?

(1) They are diffusible—*i. e.* have the property of osmosis, or passing through an animal membrane. This is of great importance in digestion, for if this property were absent no animal food could be absorbed from the intestines. (2) They are very freely soluble in water and neutral solutions. (3) They do not respond to the chemical tests for other proteid substances. They are not precipitated by heat and the mineral acids, but are precipitated by tannic acid, picric acid, or by the bichloride of mercury.

What is the name given the food after digestion in the stomach ?

Chyme. The action of the pepsin in converting proteids to peptones is called a *proteolytic* action, and chemically its action is to cause a hydration of the proteid molecules.

What forms of peptones occur?

(1) Parapeptone,—acid albumin, which results from incomplete action of the gastric juice; (2) antipeptone,—a form on which pancreatic digestion has no effect; (3) hemipeptone,—a form in which pancreatic digestion has the effect of producing leucin and tyrosin.

What conditions favor gastric digestion?

The temperature of the body is most favorable, and the presence of acid—preferably HCl—is essential. Digestive secretion does not continue except during the presence of food.

What is the milk-curdling ferment?

Milk is curdled in the stomach by a ferment, aside from pepsin, which is derived from the gastric juice. This action takes place in the absence of hydrochloric acid. Rennet (derived from the fourth stomach of calves) is used for this purpose in the cheese manufacture.

How are non-nitrogenous bodies affected by the gastric juice?

Starches are unaffected. Sugar is dissolved and cane-sugar (saccharose) is changed to grape-sugar (glucose) by the aid of the mucus present. Fats are unaffected, except that the albuminous capsules of fat-cells in adipose tissues are digested and the oil set free in globules.

What is the time required for the stomach digestion?

The time varies, with the kind and amount of food, from one to five or six hours. Digestion is favored by rest of the stomach before eating, by gentle exercise of the mind or body, by an undisturbed mental condition, and by a healthy condition of the body.

Does absorption take place from the stomach?

No, except in a very slight degree.

How does the stomach empty itself?

The stomach is elastic, and is supplied with circular and longitudinal muscles in its middle coat. These muscular fibres are capable of producing peristaltic movements of the organ which turn the food over and over during the process of digestion. This elastic pouch is closed at each end by strong, sphincter-like circular bands of muscle at the cardiac and pyloric openings, and until the stomach digestion is well advanced none of the contents escapes;

but as the peptone-making advances the pyloric opening permits the escape of chyme, and this is aided by strong peristaltic efforts on the part of the stomach at its pyloric end. Toward the end of digestion the pylorus permits the escape of undigested as well as of digested matter. The circulation of the stomach contents is circumferentially toward the pylorus, but centrally toward the cardiac opening.

What is the capacity of the stomach?

About a quart in the adult, but its muscular walls enable it to contract so as to fit its contents if much or little.

What is the nervous mechanism of stomach digestion?

The pneumogastric and sympathetic (splanchnic from solar plexus) are the nerves which supply the stomach, and besides these there are numerous ganglia in the stomach-walls. The ordinary motion-stimulus of the organ lies in the intrinsic ganglia. Irritation of the pneumogastric nerve causes contraction; its division, cessation of peristalsis. But, further than this, the vagus has control to considerable degree over secretion in the stomach.

Describe vomiting.

The regurgitation of food from the stomach through the cardiac orifice, and thence through the mouth, may occur when the cardiac opening is free and the pylorus is closed. This is usually a reflex act, and is performed by the contraction of the stomach, aided by the pressure of the abdominal muscles opposing the fixed diaphragm. It may be described as a reversed peristalsis. The stimuli which excite the reflex may be either local in the stomach or peripheral. Violent irritation of the gastric mucous membrane will excite it; also mental impulses, from ocular, auditory, or olfactory sources; injury or irritation of the testis, ovary, kidney, etc.; unusual motion, as swinging; certain diseases; and effort of will in some is sufficient.

How is this reflex controlled?

By a centre in the medulla oblongata acting through the pneumogastric nerve.

What is meant by rumination in man?

Some few persons have the ability to force half-digested food back from the stomach into the mouth, remasticate it, and again swallow it.

What do we mean by "intestinal digestion"?

Soon after passing the pylorus, food comes in contact with the alkaline secretions of the small intestine and of the liver and pancreas. In the small intestine the food is still further prepared for absorption, and from this part of the alimentary tract the digested food is taken up for body nutrition.

Describe the process of digestion in the small intestine.

By the peristaltic action of the gut the food is carried on through the length of the organ, but its progress is more or less impeded by the valvulæ conniventes. These folds of the mucous coat not only retard the too rapid advance of food, but cause it to be thoroughly exposed to the action of the digestive fluids.

How is the peristaltic action regulated?

By the sympathetic system of nerves. Auerbach's plexus lies between the circular and longitudinal muscular coats. It is also known as the plexus mesentericus.

How is the blood-supply regulated?

Also by the sympathetic system. Meissner's plexus lies beneath the mucous coat, and is regarded as the source of control of the blood-supply and of the function of absorption.

What are the glands peculiar to the small intestine?

Lieberkühn's, Brunner's, and Peyer's glands.

Describe Lieberkühn's glands.

These glands (or follicles or crypts) are thickly distributed over the whole surface of the small and large intestine, being larger in the large intestine. They are simply tubular depressions in the mucous membrane, lined with columnar epithelium, which contains occasional large "goblet"-cells.

What are Brunner's glands?

They are found in the duodenum alone, and are situated in the submucous tissue. They resemble the pyloric glands of the stomach, and, like them, are usually compound glands. The duct of the gland passes up through the mucous membrane and opens at its surface.

What are Peyer's glands?

These are of two varieties: (1) solitary; (2) agminate.

(1) Solitary glands consist of a rounded mass of whitish adenoid tissue about $\frac{1}{25}$ to $\frac{1}{10}$ in. in diameter, situated in the submucous tissue, but often projecting to the surface of the intestine. Each lymphoid mass is surrounded by Lieberkühn's follicles.

(2) Agminate glands (Peyer's patches) consist of groups of these adenoid masses, making "patches" in the mucous membrane $\frac{1}{2}$ to 3 in. long and about $\frac{1}{2}$ in. wide.

What is the function of the intestinal glands ?

Secretion of the intestinal juice (succus entericus).

What is the function of the intestinal juice ?

Its effect upon digestion is not fully understood, but it probably has some effect upon saccharose, and possibly upon proteids, converting the one into glucose and the other into peptones. However, its chief function seems to be to supply the loss of fluid to take the place of that which is absorbed as digestion progresses. At any rate, the contents of the small intestine as they enter the colon are about as fluid as when they leave the stomach.

What other glands discharge their secretions into the small intestine ?

The pancreas and the liver.

Describe the pancreas.

The pancreas is an organ lying in the upper part of the abdomen in contact with the duodenum : in length it is about 6 in., and is thicker at its right or duodenal end. It is a conglomerate gland, resembling in structure the salivary glands. During digestion it is active, but is quiescent in the intervals. Its secretion, pancreatic fluid, is discharged into a main duct which receives branches from the lobes of the gland, and is emptied with the bile through a common opening about 2 or 3 in. beyond the pylorus. During digestion the cells of the organ become granular, and the granules are thought to consist of the substance from which the ferments of the pancreas are derived, *zymogen*, rather than of the ferments themselves.

What are the characteristics of pancreatic secretion ?

The pancreatic juice is a clear, colorless fluid, having an alkaline reaction and a notably viscid consistency. It coagulates with heat, and is made quite gelatinous by cold. Specific gravity, 1015. Its composition varies, but in general is as follows :

Water	90
Organic matter :	
Ferments,	
Serum albumin,	} 9
Alkali albumin,	
Fats, soaps, etc.,	
Inorganic salts (chiefly sodium carbonate) . . .	1
	<hr/> 100

What are the pancreatic ferments?

(1) Trypsin, a peptone-forming (proteolytic) ferment, which continues the digestion of proteids begun in the stomach. It forms a peptone which resembles the stomach peptone in its reactions. This ferment, unlike pepsin, only acts in an alkaline medium. It acts less vigorously upon gelatins and other nitrogenous bodies.

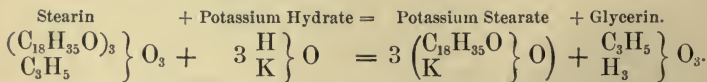
(2) Amylopsin, a starch-changing (amylolytic) ferment, by which starch is converted to maltose, and finally glucose, as by the ptyalin in the saliva.

(3) ——— (unnamed), a rennet or milk-curdling ferment. This ferment will act in the presence of an acid.

(4) Strypsin (?), a questionable ferment by which fats are broken up from the large globules and emulsified or saponified in alkaline media. It is claimed by some that this is not a ferment action, but is the result of the action of the alkaline intestinal contents upon the fat.

Of these processes the emulsification, or breaking the fat-globules into minute particles, is by far the more important, as it allows this form of food to be absorbed from the gut. Milk is an excellent example of a natural emulsion.

Saponification (or soap-making) results from the fatty acid combining with an alkali, forming the corresponding salt and glycerin—*e. g.* :



What is the function of the pancreatic juice?

It is most active in the digestion, and is peculiar in having an effect upon all forms of food which require preparation for absorption—upon proteids, starches, and fats, as well as upon milk.

What conditions favor the action of the pancreatic fluid?

Moderate heat (100° F.), an alkaline medium, and the removal of the products of the ferment-action as soon as the change is completed.

What name is given to the intestinal contents of the pancreatic digestion?

Chyle.

Describe the liver.

The liver is the largest gland in the body, and is situated in the upper part of the abdominal cavity. It secretes a fluid known as the bile or gall, which is stored in a bladder lying attached to its lower surface. The functions of the organ are—(1) secretion, and (2) the elaboration of the blood.

What is the character of bile?

It is a viscid, almost ropy fluid, of a yellow or red or greenish color and bitter taste. It is faintly alkaline or neutral in reaction, and has a specific gravity of about 1020. Its composition is, approximately—

Water	86
Organic matter, { Bile salts, 9 Fat and cholesterin, 1 Mucus and pigments, 3 }	13
Inorganic salts	1
	100

How is the flow of bile excited?

The secretion of the liver is stored in the gall-bladder until its flow is excited by the acid discharge of the stomach-contents into the duodenum. It is an active secretion, and not a passive filtration from the blood, for if a manometer-tube be fastened in the duct it will indicate a pressure greater than that of the blood. While the gall-bladder acts as a storage reservoir, the bile does not necessarily enter it, but may discharge directly from the hepatic into the common duct. The opening of the common duct into the duodenum is guarded by a sphincter-like arrangement of the muscular fibres in the gut-wall. The gall-bladder and the gall-duct are provided with unstriped muscular fibres, so that they may empty themselves. Inspiration and expiration bring alternating pressure upon the gall-bladder, and aid in emptying it.

What is the quantity of bile secreted daily?

The quantity varies with the amount of food taken, but is estimated to vary between 20 and 40 ounces, or, approximately, from a pint to a quart, in twenty-four hours.

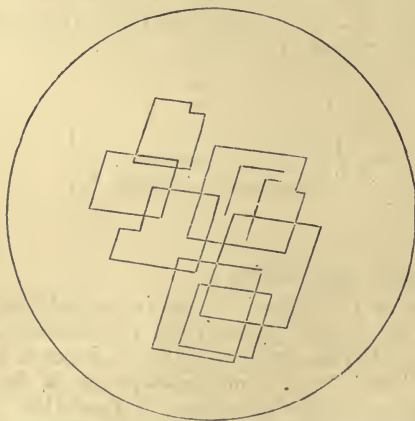
What is the resemblance between bile and meconium?

There are strong similarities. Meconium contains considerable proportions of bile salts and pigment, as well as cholesterin. It is supposed that in the fœtus the liver has the function of purifying the circulating blood and excreting certain offensive matters in this way.

What are some of the more important ingredients of bile?

(1) *Bile salts*, sodium glycocholate and sodium taurocholate. They may be isolated in crystalline form from bile, and are pres-

FIG. 10.



Cholesterin from the Contents of an Encysted Tumor.

ent in human bile in about equal proportions. They are soluble and very deliquescent colorless crystals which have the bitter taste of bile. Test by Pettenkofer's method: Add to a solution of bile a small amount of a solution of cane-sugar. On treating this solution with pure sulphuric acid drop by drop there is first a precipitation of a turbid sediment (cholic acid). This is cleared

by a further addition of sulphuric acid, and the solution assumes a bright cherry color, changing to violet, and, if much bile be present, to deep purple.

(2) *Coloring matter* of the bile, biliverdin and bilirubin. Both pigments are found in human bile, but the former is characteristic of the bile of herbivora, and the latter, bilirubin, of the bile of carnivora. The pigments are crystallizable, and are insoluble in water. The crystals have the green and red colors of the pigments. Test, "Gmelin's bile test:" Add fuming nitric (nitroso-nitric) acid, and there results a play of colors which is best seen when the bile solution is in thin layer on a white plate. The presence of the bile-pigments is shown also by absorption-bands in the spectrum. Bilirubin is probably derived from hæmoglobin, and biliverdin from the bilirubin, as they are chemically closely allied.

(3) *Cholesterol*, a crystallizable, insoluble substance which belongs to the alcohol group in chemical composition. Best recognized by microscopic appearance of crystals (Fig. 10), though it may be tested chemically by the addition of sulphuric acid, which gives a red reaction.

What are the functions of the liver?

This must be considered to be still a somewhat unfinished problem, but we can safely assume three duties: (1) that of excretion, (2) as an element in the process of digestion, (3) the elaboration of absorbed food before passing it into the blood-circulation. Of these uses, (1) and (2) are dependent upon the secretion of bile; (3) is an intrinsic property of the organ.

What excretory function has the liver?

The bile for the most part, in normal conditions, is a sort of circulating fluid: it is secreted by the liver, poured into the intestines, and reabsorbed from them, to be returned through the portal vein to the liver for recirculation. There is, however, a small proportion of biliary matter, about one-sixteenth, which is not absorbed, and this consists chiefly of the pigments of the bile. The salts are nearly all reabsorbed in the assimilation. Further than this, the liver is found to, so to speak, filter materials which would be poisonous if circulating in the general system, and either to reject them at once or to store them up and reject them slowly back to the intestine. The excrementitious material from the liver is known as stercobilin. Stercorin is found in the fæces, and is thought to be an excretion of the liver: it closely resembles cho-

lesterin, and is supposed to be a modification of cholesterin by digestion. Whether or not the stercorin (cholesterin) is an excretion of the liver corresponding to the urea of the kidney is somewhat uncertain.

What effect has bile upon the digestion?

(1) The alkaline reaction of the bile aids the pancreatic and checks the pepsin digestion; it aids in the emulsion of the fats, and is probably very active in this process. (2) It moistens the mucous membrane and favors the absorption of digested food. (3) It acts as a natural purgative and as a natural antiseptic, and in this way is very essential to the proper performance of the digestive process. As a purgative bile acts by stimulating peristalsis.

What is the effect of the liver upon absorbed chyle?

(1) Peptones resulting from the digestion of proteids undergo some modification in the liver, for it is found that if injected into the portal vein they do not appear in the urine, while if injected into the general system they do appear. This matter is not fully understood as yet, since the change the peptones undergo in the lymphatic vessels, to allow absorption without relation to the liver, is still in the dark.

(2) The liver normally forms a substance resembling starch in its chemical composition. This is known as glycogen, and is formed from glucose taken up by the portal circulation. Its chemical formula is that of starch ($C_6H_{10}O_5$), and it is derived from glucose ($C_6H_{12}O_6$) by dehydration, and is rapidly changed by diastatic ferments to glucose. This process is known as the glycogenic function of the liver: its use is supposed to be the storage of a fund of carbohydrate material (an "animal starch") to maintain a steady supply to the system.

What is the duty of the large intestine in digestion?

The chyme which enters the large intestine still continues in the influence of the ferments, and the process of digestion continues. The food may undergo acid fermentation here, but there is no new digestive action. That the large intestine may have the power of acting upon food is shown by the absorption of fats, proteids, etc. which are taken in nutrient enemata.

Describe defecation.

The expulsion of the refuse of digestion from the intestine is partly a voluntary act, but more especially reflex. The voluntary

act is the pressure of the abdominal muscles upon the contained viscera, while the reflex is an increased peristalsis in the sigmoid flexure and rectum and the relaxation of the sphincter. The centre which governs this act, so far as it is reflex, lies in the lumbar region of the spinal cord.

ABSORPTION.

What is absorption?

The digested food is taken from the intestines and carried into the blood, whence it is taken to nourish the cells. This process we know as absorption. The same term is applied to the removal of worn-out material from the tissues.

By what channels is food absorbed from the intestines?

By the blood-vessels and lymphatics.

What property of chyle renders it fit for absorption?

The property of passing through animal membranes. Chyle is the name given to food after digestion. By digestion the proteids, starches, and fats, which were not dialyzable, have become peptones, sugars, and emulsified fat. All these products of digestion are readily capable of dialysis, and therefore ready for absorption.

What is dialysis?

By dialysis we mean the property of fluids which enables them to pass through animal membranes—osmosis. This we have seen is possessed in a high degree by the ingredients of chyle. The reverse process may occur, and fluids (serum) from the blood may similarly be drawn into the intestinal canal, as is seen when the salines are used as purgatives.

What anatomical features of the gut favor absorption?

(1) The valvulae conniventes greatly increase the area of the intestinal surface, and by their shelf-like formation delay the advance of chyle. (2) The villi of the intestine not only increase the area, but are the special organs of the function of absorption. (3) The contraction of the intestine upon its fluid contents also favors, mechanically, the filtration of the contents through its walls.

What are the villi?

The villi are almost innumerable, minute, teat-like projections from the surface of the wall of the intestine. They are very numerous in the small intestine, and none are found in the large

gut. Each villus is covered by an epithelial layer, and within, supported by areolar tissue, is a delicate capillary network of blood-

FIG. 11.

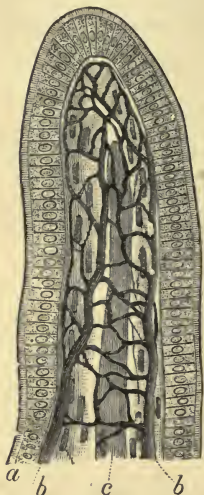


FIG. 12.



FIG. 11.—An Intestinal Villus: *a*, layer of cylindrical epithelium, with its external transparent striated portion; *bb*, blood-vessels entering and leaving the villus; *c*, lymphatic vessels, occupying its central axis (Leydig).

FIG. 12.—Patch of Peyer's Glands, from the lower part of the ileum, showing villi (magnified).

vessels, a muscular layer (*muscularis mucosæ*), and a more or less branched ending of a lacteal vessel (Figs. 11 and 12). The ileo-cæcal valve shows the absolute alteration which is apparent in the mucous membrane of the small as compared with the large intestine. On the side toward the ileum are found villi in great numbers, while its cæcal side shows none.

Where does the absorption occur in the intestine?

Probably throughout its length in some degree. In the stomach and large intestine the absorption is very much less than in the small intestine, but there is reason to think that there is considerable activity of absorption from the entire gut so long as digestion continues.

What becomes of the food absorbed by the blood-vessels?

It is taken by the portal vein to the liver, and there further elaborated for tissue-nutrition.

What becomes of the food absorbed by the lacteals?

It is collected from all the lymph-spaces in the villi and about the glandular structure of the intestines, and is taken thence into the larger lacteals, whence it passes through the mesenteric lymphatic glands and into the receptaculum chyli of the thoracic duct (Fig. 13). Hence it passes on into the blood-vascular system, which it joins at the root of the neck at the union of the left internal jugular and subclavian veins.

Does chyle undergo change in the lacteals?

Yes. Peptones, as such, are not found in the blood nor in the thoracic duct, and in the same way sugar is not more abundant in chyle after absorption than in the blood; nor can we fully account for the fats which are absorbed. The trace is lost, to a great degree, after absorption of most substances, and we do not know the exact history of the metamorphoses which render them fit for tissue-building.

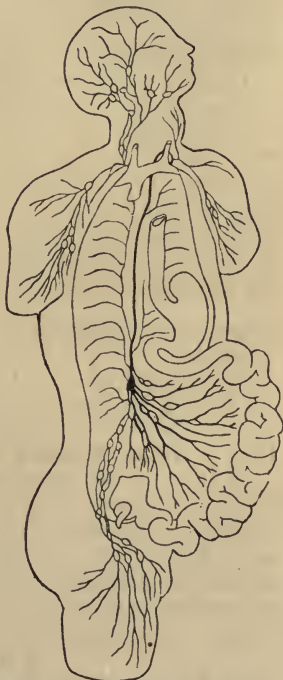
What elements are chiefly taken up by the portal system?

All elements to a greater or less degree, but the crystallizable substances are taken up in greater proportion by the blood-vessels than by the lacteals. Thus we find that sugars and salts seem to pass into the portal system, and the proteids and fats into the lacteal system in a little greater proportion.

What is the appearance of chyle in the lacteals?

It is opaque, whitish, milky from the minute fat-globules which

FIG. 13.



Lacteals and Lymphatics during Digestion.

are suspended in it (emulsion). The basis of the fluid found in the lacteals is lymph, and it is only during digestion that the lymph in the visceral lacteals becomes chylous.

What is the character of lymph?

It is a limpid, watery fluid, which differs from blood-plasma only in that it is somewhat more watery. Like plasma, the lymph coagulates or clots on exposure to the air, but the clot is not so firm, and the clotting is due to the presence of fibrinogen and globulin. Chyle is lymph in which there is present an increased amount of fatty and proteid material.

What conditions favor the absorption of food?

To be absorbed by the blood-vessels or lacteals we must have substances in (1) a fluid state, and the more dilute in solution the more ready the absorption; insoluble substances are not appreciably affected by this process, nor are any dense solutions readily taken up. (2) The rapid removal of the absorbed matter and the renewal of fresh blood in the capillaries is of importance. Thus, if the portal circulation is obstructed, so that the blood is circulating slowly or the capillaries are tense from intravascular pressure, the absorption will be slow.

What is the quantity of chyle which is taken into the system daily?

This is somewhat problematical, but it is estimated to be about one-half to two-thirds of the volume of the blood.

How is lymph propelled in the lymphatic vessels?

In the villi are bands of unstriated muscle (*musculi mucosæ*), which act to propel it into the larger channels; muscular pressure upon the lymph-vessels and intrinsic contractile power of the vessel-walls help it along; while the pumping force of the respiratory movements and the "negative pressure" in the great veins are of great value in maintaining the circulation.

ANIMAL HEAT.

What is the normal temperature of the body?

98.5° F. (37° C.). This temperature is not invariable, but in the superficial cavities, mouth, and axilla, which are convenient for ascertaining the body-temperature, this is nearly exact. In the in-

ternal organs the thermometer may indicate as high as 100° F. in normal conditions. In the rectum the temperature is about 1° F. higher than in mouth or armpit.

Is this normal temperature constantly maintained?

Yes, with very trifling variations. Under all circumstances the healthy body maintains about this temperature, varying very slightly under torrid and frigid climates. There are also slight variations from exercise, age, etc.

How is this heat maintained?

It is produced from union of the oxygen of the air, which is taken up by the blood in the lungs, with carbon and hydrogen. This is an exact analogy of combustion in the air.

What products result from this combustion in the body?

Carbonic oxide and water.

What is metabolism?

It is a change constantly going on in the body by which the protoplasm of cells is destroyed in doing work (destructive metabolism), and by which new protoplasm is built up by the assimilation of food (constructive metabolism). When any group of cells is in active use (*e.g.* in a muscle) the destructive process is rapid and the formation of carbonic oxide and water is active; in other words, there is active combustion of the cells with the production of heat. Simultaneously, there is reconstruction of the used protoplasm, but this process is not accompanied by the creation of heat.

How is the loss of heat regulated?

(1) The blood at the surface of the body is cooled by the colder air or by evaporation of the sweat. This is automatically regulated by the vaso-motor nerves, for upon exposure to a colder atmosphere there is immediate contraction of the superficial capillaries, and upon entering a warmer environment there is dilatation; so that the quantity of blood presented for cooling is an inconstant factor, depending upon external temperature. The sweat-production is similarly under reflex control.

(2) Loss of heat is considerable by the lungs, though less than that from the skin: the air is warmer, in usual conditions, after leaving the lungs than before it has entered them.

(3) Clothing and the protection afforded by houses, and the elevation of the temperature of air indoors by fire, are factors in the regulation of the body-temperature.

What is meant by heat-centres in the brain?

There are reasons for believing that there are nervous centres exciting the heat-production in the tissues (thermogenic centres), and centres which check the metabolism of tissue, and thus control the temperature (inhibitory heat-centres). This is not entirely proven, nor can these centres be localized. We do know that the innervation of a part is necessary for the maintenance of its warmth, aside from vaso-motor causes for alteration of temperature.

What are the extreme limits of body-temperature found in life?

In ordinary pathological conditions the temperature does not remain long at a point below 95° F. or above 105° F. without fatal results. Under extreme conditions of prolonged exposure to cold and the algid stage of cholera recovery has occurred after a bodily temperature as low as 75° F. On the other hand, in some cases of extreme fever, as from sunstroke, recovery has been noted after a temperature of 110°–112° F. has been observed.

SECRETION.

What are secretions?

Materials separated from the blood by the cells to serve some further purpose in the animal economy. These secretions are for the most part elaborated by the glands, though the mucous and serous membranes act in this capacity as well. Examples of secretions are found in milk, bile, gastric juice, tears, etc.

What are excretions?

Materials which are separated from the blood by cell-activity and discharged from the body, being either useless or harmful if retained; *e. g.* urine, sweat.

What is the function of the serous secretions?

Lubrication of surfaces in which friction is undesirable. Such conditions are found in the pleural cavity, peritoneum, tunica vaginalis, and in a similar way in the synovial cavities of joints, tendon-sheaths, etc.

What is the function of mucus?

To lubricate and moisten the soft and delicate cells of mucous membrane. Mucous tracts which are so protected are the digestive, respiratory, and genito-urinary.

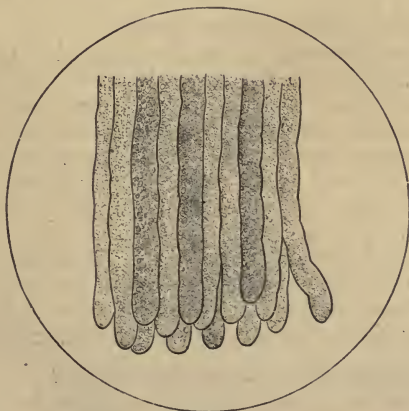
How are these processes of secretion and excretion carried on?

By means of the activity of the cells. In most cases the cells are grouped in organs which are known as glands. The serous fluids are the only notable exception to this rule, the endothelial cells secreting without the intervention of complex anatomical groups.

What forms of secreting glands occur?

1. *Simple tubules*, or *tubular glands*, which are pits or depressions in epithelial surfaces lined with epithelial cells. The mucous surfaces furnish the most numerous examples of this form of gland, follicles of Lieberkühn (Fig. 14), tubular (mucous) glands

FIG. 14.



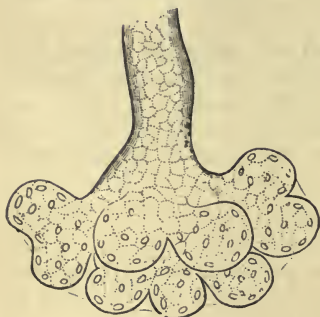
Follicles of Lieberkühn, from small intestine of dog.

of the stomach; but the skin, in the sweat-glands, shows a more complicated form of tubular gland in that it is convoluted and tortuous.

2. *Compound tubular glands* consist of a tubular gland which

subdivides the main tubule, so as to have several branching tubules leading into it. Often these branches again subdivide so as to form a group of ultimate glandular elements grouped about the main tubule, which acts as a duct. This form of gland is found in kidney, testis, salivary and mammary glands, Brunner's glands (Fig. 15), and in many of the other glandular structures.

FIG. 15.



Portion of one of Brunner's Glands, from human intestine.

3. *Racemose or aggregate glands*, in which the glandular structure is divided into lobules or *acini*. These glands may be regarded as a refinement of the compound tubular variety, and examples are found in the salivary glands and in the Meibomian follicles.

How is secretion effected by the glands?

(1) By *physical* processes—viz. filtration and dialysis—the cells are able to separate from the blood-plasma the ingredients which make up the secretion. It is important to remember that the force of dialysis may actually operate against pressure, and is, consequently, not a mere negative process; and, again, the fact that the condition of the blood as to consistency and saline ingredients makes filtration a sort of check-valve upon the permanency of the blood-condition.

(2) By *chemical* processes the cells of glands manufacture new substances not found in the blood-plasma and add them to the secretions. These processes are peculiarly noticeable in the ferment-producing glands, salivary, peptic, and pancreatic.

What circumstances affect glandular activity?

(a) If the *amount of blood passing through a gland* be increased, there will be increased activity of the function, and, conversely, as a rule, during functional activity the gland will increase in vascularity. The stomach, for example, during digestion is quite engorged, and when idle is supplied with much less blood, as is seen by the color deepening during its period of activity.

(b) An *increase in the material upon which the gland acts* stimu-

lates the gland to greater effort and increases the production of the gland. Thus, the amount of urea is increased by an increase of nitrogenous waste, as by exercise, or by an increase of nitrogenous matter in the blood, as by a full meal of animal food.

(c) The *nervous system exerts an active influence* upon secretion. This is usually reflex in character, and frequently is active through the vaso-motor nerves, as when the salivary and gastric secretions are increased by the sight or smell of food, as well as by its actual administration. There is also a so-called *trophic* influence of the nervous system, which directly affects the secreting power of a gland: this is especially well shown in the case of the chorda tympani in its relation to the secretion of the submaxillary gland.

Describe the correlation of the secretions.

There often seems to be a relation in the amount of one secretion to that of some of the others; thus in a diseased condition of the intestinal mucous membrane, with increased secretion, there will often be an increase of the bile secreted, and perhaps a diminution of other secretions, as salivary or urinary. And, again, unusual perspiration is followed by decrease in the activity of the kidneys.

THE MAMMARY GLANDS.

Describe the mammary glands.

They are large glands which are made up of several distinct lobes. Each lobe has its duct, which leads to the nipple, and there are about twenty such lobes and ducts. The lobes are subdivided, and the small lobes, lobules, or alveoli are made up of the terminal tubules of the duct, which lie in a mesh of fibrous alveolar tissue containing considerable fat in its reticulum. The ultimate divisions of the duct (alveoli) are lined with columnar epithelial cells, as are the ducts and their branches, but the epithelium of the ducts becomes flat (squamous) near the nipple. The main ducts (lactiferous ducts) are sacculated, and during lactation the secretion of the alveoli collects in them, and is drawn from them through their small orifices in the nipple. The flow of milk is also aided by the presence of a small amount of unstriped muscular fibre in the wall of the ducts.

The mammae are abundantly supplied with blood-vessels, lym-

phatics, and nerves, and during pregnancy and lactation the vessels, as well as the gland, undergo considerable increase in size.

What is milk?

The secretion of the mammary gland is a bluish-white fluid: It is opaque, and this opacity is caused by the presence of minute fat-globules which are held suspended—an emulsion. Besides the fat-globules the microscope shows in milk from a newly-active gland certain albuminous bodies which are known as colostrum-corpuscles. They are probably cells from the gland which are undergoing fatty degeneration. Milk is alkaline in reaction, and has a sp. gr. of about 1030.

Describe the composition of milk.

The ingredients of milk are water, containing in suspension fats and in solution casein, serum, albumin, milk-sugar, and salts. Human milk differs from cow's milk in containing less proteids and fats and more sugar:

	Human Milk.	Cow's Milk.
Water	890	858
Proteids	35	68
Fats	25	38
Sugar	48	30
Salts	2	6
	<hr/> 1000	<hr/> 1000

What is cream?

The fat-globules rise to the top if milk is allowed to stand, and are called cream. By agitating or "churning" the cream the albuminous envelopes of the fat-globules are broken, and they coalesce to form a fat mass known as "butter."

Why does milk "turn sour"?

The addition of an acid to milk causes the casein, which is held in solution by the alkaline sodium phosphate present, to be precipitated. The precipitation of the casein leaves behind the watery and soluble ingredients, but includes with it the fat-globules. The precipitate is known as the "curd," and the watery residuum as "whey." This process is imitated in nature by the breaking up of milk-sugar (lactose) to form lactic acid through the action of a micro-organism, *bacterium lactis*.

What is meant by milk-curdling ferments?

Certain ferments will act upon milk to cause its separation into curd and whey. These are called milk-curdling ferments. They are found especially in the secretions of the stomach, pancreas, and intestine.

How is a milk-curdling ferment utilized in the arts?

In cheese manufacture the fourth stomach of the calf (rennet) is used to curdle milk.

What causes a scum to form upon boiled milk?

The serum-albumin is solidified by heat.

What changes occur in milk at different periods of lactation?

The milk of mothers prior to and just after parturition is known as colostrum, and is deficient in casein and contains an excess of serum-albumin, as well as colostrum-corpuscles. Toward the end of lactation there is also said to be the same excess of serum-albumin and lack of casein.

How are the fat-globules of milk secreted?

It seems probable that two methods are possible: (1) The epithelial cells of the gland seem capable of causing a metabolism of proteids to form fat; (2) the cells themselves may undergo a fatty metamorphosis.

What is the value of milk as a food?

As the food of all young animals it has to be considered of the greatest importance; besides this, as a direct food, both in the natural state and in the derived forms of butter and cheese, it is one of the most used articles of adult diet. The causes which lead to its choice in the dietary are easily seen: it contains all the elements necessary to sustain life—water, proteids, carbohydrates, and salts. As an exclusive diet it will probably sustain life better than any other substance.

THE SKIN.**Describe, roughly, the structure of the skin.**

There are two layers of tissue which form the entire thickness of the skin. The superficial epithelial layer is known as the *epidermis* or *cuticle*; the deeper stratum, in which lie the active functional elements, is called the *cutis vera*, *corium*, or *derma*.

What is the function of the epidermis?

The epidermis is a stratification of epithelial cells of varying thickness. The epithelium is flat and horny at the surface, in the deeper portions are flattened and polyhedral cells, and it is closely adapted to the surface of the corium beneath it. In its deeper layer is found the pigment which characterizes the complexion of individuals and of races. Its function is purely one of protection. The growth to replace worn-out cells is very rapid, and in cases of considerable use of a part, with interrupted pressure upon the skin, the cuticle becomes very thick and horny, as is often seen upon the hands and feet. The hair and nails are modifications of the epidermal epithelium.

Describe the structure of the corium.

The true skin is a tough, elastic tissue composed of interlacing bundles of connective-tissue cells containing spaces between the fasciculi. These spaces are known as *areolæ*. There are also numerous unstriped muscular fibres. This structure lies upon a more or less thick layer of fatty or loose cellular tissue. In the cutis are found the active organs of the skin—the papillæ, sweat- and sebaceous glands, and the hairs (Fig. 16).

What are the papillæ and their uses?

Upon the superficial surface of the cutis vera are innumerable minute elevations which project into the epithelium. They are very vascular, and contain the nerve-endings which give to the skin its sensibility, the sense of touch. The papillæ are especially abundant upon the parts in which this sense is most acute—palms, fingertips, soles.

Describe the sweat-glands.

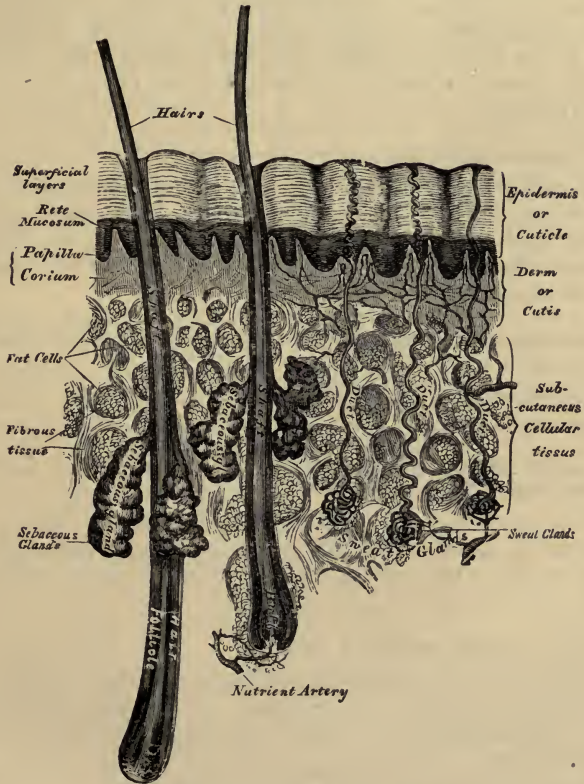
Each gland lies in the subcutaneous fat, and consists of a convoluted mass of tubules which terminates in a duct leading up through the derma and epidermis, discharging the secretion of the gland through a minute opening. This secretion is known as perspiration or sweat.

What is meant by the term "insensible perspiration"?

When the secretion of the sweat-glands forms in drops upon the skin, we speak of this as sensible perspiration or sweat. However, at all times the glands continue active and the fluid evaporates rap-

idly, so that no moisture is noticeable upon the surface ; and we call this the insensible perspiration.

FIG. 16.



Sectional View of the Skin, magnified.

What is the sweat ?

It is a watery fluid, colorless, slightly turbid, slightly salty to the taste, of acid reaction, and possessing a peculiar odor. It is an excrement. Its composition is somewhat variable, but in general it

may be said to contain about $\frac{1}{2}$ per cent. of solids suspended and dissolved in water. These solids are fats and fatty acids, sodium chloride, epithelium, and a trace of urea. Besides these there is a considerable amount of carbonic dioxide (CO_2) excreted by the skin.

What is the amount of sweat excreted in twenty-four hours?

About one and a half to two pints, but this varies greatly with the environment.

What factors affect the amount of the sweat?

The condition of the atmosphere, the nature and quantity of the food, the amount of fluids consumed, the exercise taken, and the relative activity of the other glands, especially of the kidneys. Certain mental conditions, some diseases, and drugs also interfere with sweat-secretion.*

What ingredients produce the characteristic odor of perspiration?

The fatty acids—formic, acetic, butyric, propionic, caproic, and caprylic—have been found. The odor of sweat varies in different portions of the body.

Upon what nervous mechanism does the production of perspiration depend?

It is probable that the sweat-glands are under the reflex control of centres in the medulla and in the spinal cord, and that these centres regulate this function of the skin through the vaso-motor system.

Is sweat-excretion necessary to life?

Yes, because of the disturbance of heat-regulation by absence of evaporation, or, perhaps, by absorption or retention of poisonous matter. The symptoms are those of an acute poisoning—pyrexia and exhaustion.

What is the character of the sebaceous glands?

The sebaceous glands occur everywhere over the entire skin sur-

* Under conditions which exaggerate the flow of the perspiration, as hard work in hot air, with free consumption of fluids, the amount of the perspiration is said to exceed twenty pints in a day.

face with the exception of the palms and soles, and most abundantly in the hairy parts. They are intimately connected with the hair-follicles, and their ducts, as a rule, open into the follicles, though sometimes they discharge separately. The glands are aggregate glands; that is, are formed by the subdivision of the duct to make up the lobules of the gland. There is a delicate plexus of capillary vessels about the sacculi.

What do they secrete?

The secretion of the sebaceous glands is a soft, oily, white material, and has, besides other fats, stearin for basis. Its use seems to be to lubricate the skin, keeping it soft and flexible, and at the same time, by its oily nature, to prevent maceration of the skin by continued exposure to moisture, and to check the undue absorption from the surface. Sebaceous matter is not excrementitious, but is a secretion.

Has the skin power to absorb?

It has. This function of the skin is utilized in the application of medicines, of food, and of drink in appropriate cases.

What further function has the skin?

That of regulation of body-temperature.

THE KIDNEYS AND THE URINE.

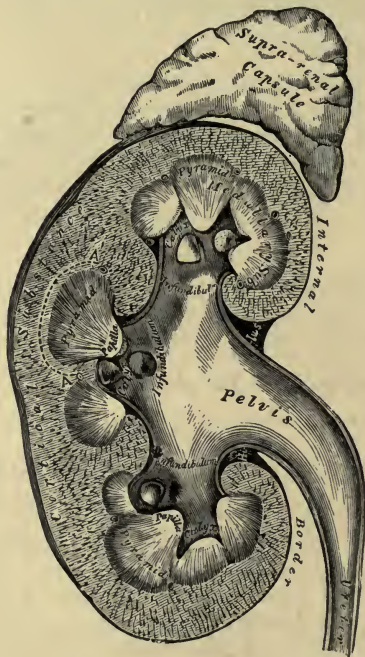
Describe the gross appearance of the kidneys.

The kidneys are glandular organs having somewhat the form of a bean. In size they are somewhat more than 4 inches in length, somewhat more than 2 inches wide, and about 1 inch thick. The weight of each organ is about 4 to 6 ounces. A thin but rather tough capsule invests the kidney (Fig. 17). This may be pulled off readily, leaving the surface of the organ smooth and even and of a deep-red color. If a vertical section of the organ be made, the central cavity (sinus) will be noticed, and about it the kidney tissue. Within the sinus are the apices of pyramidal projections, about ten in number, and if the cut surface be examined closely it may be noted that the outer (cortical) portion differs in appearance from the more central (medullary) portion. The blood-supply is from the renal artery, and the nerve-supply is from the sympathetic system through the solar plexus.

What is the function of the kidney?

The secretion of the urine. The kidney is a compound tubular gland. The medullary portion of the organ is almost entirely

FIG. 17.



Vertical Section of Kidney.

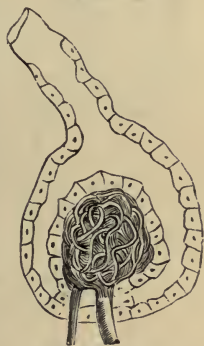
made up of tubules, which take origin in the cortex and empty upon the apices of the pyramids of Malpighi of the medullary portion.

What are the Malpighian bodies?

In the cortical portion of the kidneys are found minute tufts of

capillaries which are surrounded by a capsule lined by epithelial cells (Fig. 18), and here it is that the uriniferous tubules arise, the tuft of capillary vessels being, as it were, built into the end of the tubule.

FIG. 18.



Malpighian Body.

What are the uriniferous tubules?

Beginning in the cortex of the kidney at one of the bodies of Malpighi, the minute secreting ducts pursue a tortuous course to the larger collecting tubules, which empty at the apices of the pyramids of Malpighi into the calyces of the kidney. Without entering minutely upon the course of the tubules, it is important to remember that they form a loop (of Henle) which dips into the pyramid, and that they pursue a somewhat tortuous course both before entering into the loop of Henle and upon returning to the cortical portion of the kidney, where they empty into the straight collecting tubules. The straight course of the arms of Henle's loop and of the collecting tubules gives to the pyramids a finely striated appearance. (See Fig. 19.)

Describe the blood-circulation in the kidney.

On entering the kidney the renal artery breaks up into several branches, which pass into the tissue proper of the organ. Branches from these arteries (*arteria propria renales*) have two determinations—(1) into the cortex, and (2) into the pyramids.

(1) Those branches (*interlobular*) which pass into the cortex divide to become the *afferent* vessels to the Malpighian bodies, and, after there passing through the capillary tuft, the blood is re-collected and goes out by an *efferent* vessel. This efferent vessel in its turn is broken into a minute capillary plexus which surrounds the uriniferous tubules in the cortex of the kidney, and these capillaries unite to form the venous return circulation. Thus, *this system has, it is to be noted, two capillary divisions, in the Malpighian tuft, and again about the tubules of the cortex.*

(2) Numerous minute branches (*arteriæ rectæ*) are given off, which pass into the pyramids, surround the portion of the uriniferous tubule (Henle's loop) which passes into the medullary

FIG. 19.

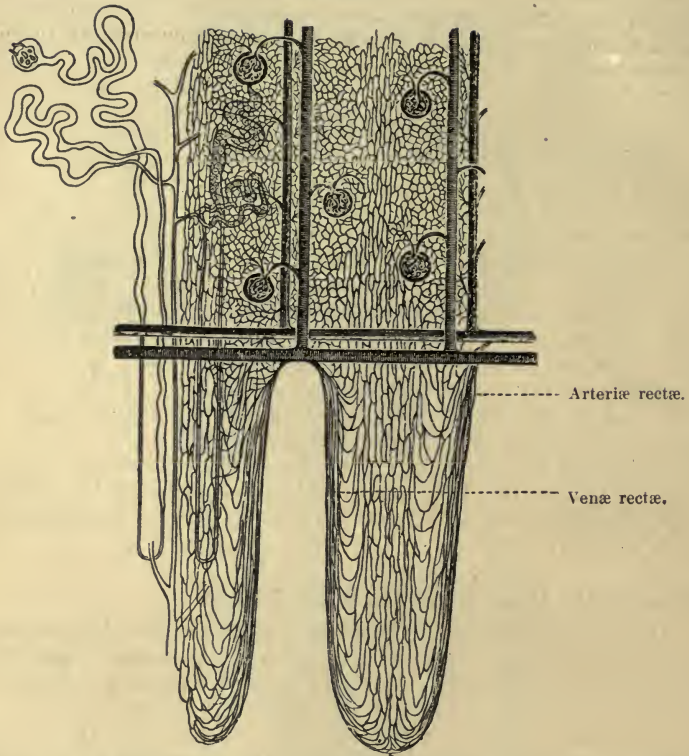


Diagram of the Tubules and Vascular Supply of the Kidney. On the left is a tubule alone; in the middle is a tubule along with the blood-vessels; on the right are blood-vessels only.

region of the kidney, and return (venæ rectæ) to join the branches from the cortex and form the venæ propriæ of the kidney.

How do the kidneys secrete urine?

(1) By filtration, and (2) by real functional action of the epithelium.

(1) In the circulation of the blood through the Malpighian tuft there seems to be no active separation of the urinary ingredients

by cell-power, but the water and saline elements are given off here by the blood by a process of simple filtration. The amount of fluid which passes here is governed by the blood-pressure in the arteries of the kidney and by the fluidity of the blood.

(2) The epithelium of the uriniferous tubules has secreting function, and is able to *separate* from the blood foreign substances (*e. g.* indigo-carmin) and eject them into the tubules, and to *manufacture* from material taken from the blood new substances not found there (*e. g.* urea and pigments).

What is the course of the urine after leaving the kidney?

The urine collected in the tubules of the kidney passes into the pelvis, and is carried to the urinary bladder in irregular quantities by the ureter. The ureters simply act as ducts, and do not store up urine, nor do they usually actively eject it into the bladder. As a few drops of urine collect in the pelvis of the kidney, they run into the bladder, the action of the two kidneys not being in alternation nor absolutely regular in point of time. Regurgitation from the bladder is prevented by the oblique course of the ureter through the muscular wall of the bladder.

Describe the act of micturition.

When the bladder is filled the act of emptying it is called micturition. It is a voluntary act, aided by the involuntary reflex contraction of the muscular coat of the organ itself. The voluntary muscles involved are those of respiration—the diaphragm and the abdominal muscles. So far as micturition is involuntary, it is a reflex depending upon a centre in the lumbar spinal cord.

What are the physical characteristics of normal urine?

It is a clear, amber-colored fluid of slightly acid reaction. It may develop a flocculent precipitate of a light cloud of mucus upon standing. It has a characteristic odor and a salty-bitter taste.

What is the normal specific gravity of the urine?

About 1020, but under conditions of health it may vary from 1010 to 1030, or even beyond these limits.

What conditions affect the acidity of the urine?

The acidity of the urine is due to the presence of acid sodium phosphate. There is no free acid present, as is shown by the fact that no precipitate is formed upon the addition of sodium hyposulphite. The degree of acidity varies, being less during active diges-

tion and less after vegetable food. Herbivora have alkaline urine, while carnivora have strongly acid urine; but the herbivorous animal during fasting has acid urine, because it is then living from its own tissues and is for the time a carnivore. After excretion, however, the urine soon becomes more acid (probably because of the presence of some fermentation), and at this time uric acid and urates may precipitate. Upon further exposure it is attacked by micro-organisms, and the urea is changed to ammonium carbonate, the reaction becoming alkaline, and there is a precipitation of triple phosphates and alkaline urates. In the body these conditions do not occur in conditions of health.

What is the chemical composition of urine ?

The urine is an excrementitious fluid, and may be considered as a watery solution of the excrementitious products of the retrograde metamorphosis of nitrogenous bodies, resulting from the processes of life and action. Chemically, it is a solution of urea and urates with a small percentage of organic salts.

Table of the Chemical Composition of the Urine.

Water	967
Solids, crystallizable nitrogenous bodies :	
Urea	14
Uric acid, free (trace),	} . 11
Uric acid in form of alkaline urates,	
Hippuric acid and hippurates,	
Pigments, extractives, and mucus,	
All in small and constant amounts.	
Salts :	
<i>Inorganic</i> —	
Chlorides of sodium and potassium,	} . 8
Sulphates and phosphates of sodium and potassium,	
Phosphates of magnesium and calcium,	
Silicates (trace),	
<i>Organic</i> —	
Lactates, acetates, and formates, which only appear occasionally,	}
Sugar (occasionally), a trace,	
Gases, nitrogen, and carbonic acid.	

What is the daily quantity of urine secreted ?

One to two quarts. The quantity varies greatly in health with the amount of fluid taken, of food consumed, of the activity of the skin evaporation, and somewhat with the character of the food. In a more general way it may be said to depend upon the condition of the blood, an excess of fluids demanding increase of functional activity on the part of the kidneys. In conditions of disease or under the stimulus of drugs the limits mentioned are by no means final, for in certain pathological conditions the secretion may be almost wholly suspended or very greatly increased.

What conditions increase the urinary secretion ?

The conditions which favor filtration of water by the glomeruli of Malpighi; that is, the presentation of a larger amount of blood to the action of these bodies. This is accomplished—

- (1) By increasing the force of the heart.
- (2) Through the nervous system by its action upon the vascular, so as to produce local congestion. The effect of the nervous system in increasing the urine by reflex vaso-motor impulses is felt most in the glomeruli, and the urine is therefore very watery.

(3) Conditions which cause anæmia of other parts may produce a greater determination of blood to the kidneys, and so increase the urinary flow. So marked is this that the skin and kidneys may almost be said to be complementary in their action in eliminating water from the system; and in this regard their relative activity may be said to be inversely proportional to one another.

Kirke has the following table (modified from Foster), which is useful for reference :

Table of the Relation of the Secretion of Urine to Arterial Pressure (Kirke).

A. Secretion of urine may be increased—

- a. *By increasing the general blood-pressure—by*
 1. Increase of the force or frequency of heart-beat.
 2. Constriction of the small arteries of areas other than that of the kidney.
- b. *By increasing the local blood-pressure by relaxation of the renal artery, without compensating relaxation elsewhere—by*
 1. Division of the renal nerves (causing polyuria).
 2. Division of the renal nerves and stimulation of the cord, below the medulla (causing greater polyuria).

3. Division of the splanchnic nerves; but the polyuria produced is less than in 1 or 2, as these nerves are distributed to a wider area, and the dilatation of the renal artery is accompanied by dilatation of other vessels, and therefore with a somewhat diminished general blood-supply.
 4. Puncture of the floor of fourth ventricle or mechanical irritation of the superior cervical ganglion of the sympathetic, possibly from the production of dilatation of the renal arteries.
- B. Secretion of urine may be diminished—
- a. *By diminishing the general blood-pressure*—by
 1. Diminution of the force or frequency of the heart-beats.
 2. Dilatation of capillary areas other than that of the kidney.
 3. Division of spinal cord below the medulla, which causes dilatation of general abdominal area, and urine generally ceases being secreted.
 - b. *By increasing the blood-pressure*—by stimulation of the spinal cord below the medulla, the constriction of the renal artery which follows not being compensated for by the increase of general blood-pressure.
 - c. *By constriction of the renal artery*—by stimulating the renal or splanchnic nerves or the spinal cord.

What two methods of elimination, then, do we find in the kidneys?

(1) The process of filtration, depending upon blood-pressure and acting almost solely upon the aqueous elements.

(2) Secretion proper, by which cell-activity performs the function of excreting the solid matters of the urine.

What is the source of the urea?

It is not fully known whether the urea is taken from the blood as such by the kidneys, or if it is made up by the cells of the kidneys from elements taken from the blood. It is probable that the former is for the most part the source of urea, and a less amount is really composed in the cells of the kidney-tubules. At any rate, the source of the urea is the nitrogenous matters of the body: 1, those taken in as food, urea being greatly increased by a nitrogenous meal; 2, by the metabolism of the tissues. The measure of the amount of work done is, however, not found in the quantity

of urea excreted. The secretion of urea continues if nitrogenous food be absent from the diet; and the elimination is increased by increased cell-activity, and, consequently, of cell-degeneration, as by muscular work.

What is the amount of urea excreted?

The amount varies, but it may be considered to be about one-half the solid constituents of the urine. Roughly speaking, the urinary solids may be regarded as 4 per cent. of the total, and the urea (including the uric acid and urates) about 1.5 to 5 per cent. This proportion is very variable, and there may be urea in healthy urine to exceed $2\frac{1}{2}$ per cent., or in a much less ratio than 5 per cent.

Method of Estimating Solids.—A useful rule for approximately estimating the total solids in any given specimen of healthy urine is to multiply the last two figures representing the specific gravity by 2.33. Thus, in urine of sp. gr. 1025, $25 \times 2.33 = 58.25$ gr. of solids in 1000 gr. of urine. In using this method it must be remembered that the limits of error are much wider in diseased than in healthy urine.

What abnormal matters are sometimes found in urine?

In disease or after the introduction of certain foods we may find certain abnormal elements in urine—serum-albumin, globulin, ferments, peptone, blood, sugar, bile acids and pigments, casts, fats, micro-organisms, etc.

THE VASCULAR GLANDS.

What is meant by the term "vascular glands"?

Certain glandular organs which are made up largely of lymphatic tissues, but which do not seem to be connected, at least directly, with secretion or excretion. Among these glands may be mentioned, as the more noticeable, the spleen, the thymus gland, the thyroid gland, the tonsils, the suprarenal capsules, the pineal and the pituitary glands, and Peyer's glands.

What, in a general way, is the function of the vascular glands?

This cannot be fully answered, as the subject is not understood at all completely; but it may be said that their work has probably to do with the elaboration of the blood, and, further, that each of

the glands has an unknown special office beyond the function of maintaining a constant supply of red and white blood-corpuscles, and of caring for them when past usefulness. Such an opinion is based upon the disturbance of the special glands in certain diseases, and upon the great activity of these glands during foetal and infant life, when the elaboration of the blood is necessarily very rapid to maintain rapid development. In function, as well as in structure, these glands are similar to lymph-glands.

Has the spleen a special function ?

The spleen becomes considerably increased in size during digestion of food, and the tissue of the organ becomes filled with albuminous particles which gradually disappear, and hence it is inferred that there are special functions which have to do with the elaboration of the nitrogenous foods. Besides this, the spleen may be regarded as a prominent source of origin of both red and colorless blood-corpuscles, and as the organ in which many of the red corpuscles undergo degeneration when their usefulness is impaired. Furthermore, it is a very vascular organ, and is capable of very great distension, and becomes, in a passive way, a sort of safety-valve in relieving the portal system, more especially of the stomach.

Can any special function be attributed to any other of the vascular glands ?

No.

MUSCLE.

What kinds of muscular tissue are found ?

1, plain or unstriated muscle-fibres ; 2, striated muscle-fibres.

Describe the unstriped or plain muscles.

They are found in the tissues in which the will has no control, and are known as *involuntary* muscles. These muscles are made up of bundles of elongated, spindle-shaped cells. Each cell has an oblong nucleus and is flattened (Fig. 20). In length they are about $\frac{1}{800}$ to $\frac{1}{300}$ inch, and about $\frac{1}{4000}$ inch in width. The cells are bound into bundles by an albuminous cement, and these again into larger bundles by areolar tissue.

What is the appearance of the striated muscle ?

This form of muscle-tissue makes up the most of the bodily tissue, for it is found in all of the voluntary muscles. All such

muscles are made up of fasciculi of fibres of this striated muscle-tissue, each being enclosed in a sheath (sarcolemma) (Fig. 21). The arrangement of the elements of each fibre is such that its microscopic appearance is as though there were alternate light and dark bands about it, the dark being the wider. These are the elements of the muscle-tissue, the dark bands representing disks of contractile tissue, while the brighter bands represent a disk of interstitial substance.

FIG. 20.



Non-striated Elementary Fibres, from the human colon: *a*, treated with acetic acid, showing the corpuscles; *b*, fragment of a detached fibre not touched with acid.

What are sarcous elements?

The fibres may be split up longitudinally into minuter fibrils which have the microscopic appearance of alternate light and dark particles; these particles are the sarcous elements (Fig. 21, B, *d*), and it is by the fusion of these fibrils that the fibres are made up.

How large are striped muscle-fibres?

They are about an inch in length and $\frac{1}{400}$ inch in diameter. They join the connective-tissue cells of a tendon or aponeurosis or another muscle-fibre by adhesion of the sarcolemma at the ends, and thus unite the muscle-bundles in a firm mass; and this union is further strengthened by the cohesion of the fibres.

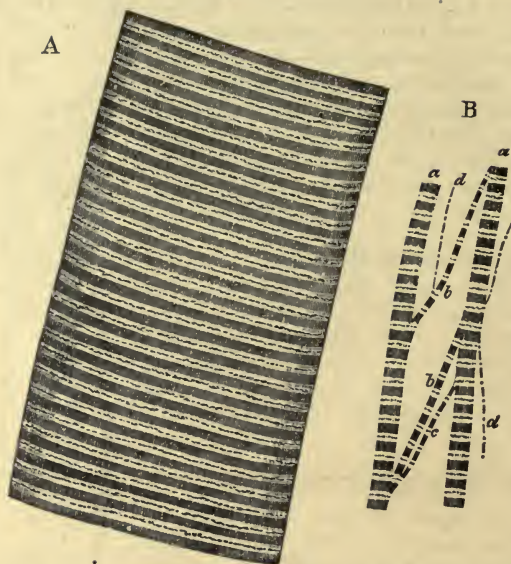
What is peculiar in the heart-muscle?

It is an exception to the rule that involuntary muscles are unstriped. The striation of the heart-muscle fibres is not so marked as in ordinary muscle, and the form of the fibres is different, for they are branched and more slender. Each fibre is nucleated, a large oval nucleus occurring at the centre. The appearance of the heart-fibres indicates that they occupy an intermediate position between typical plain and striped fibres.

What is myosin?

Myosin is an albuminoid substance belonging to the class of

FIG. 21.



A, Portion of a Medium-sized Human Muscular Fibre (magnified nearly 800 diameters).
 B, Separated Bundles of Fibrils, equally magnified: *a, a*, larger, and *b, b*, smaller collections; *c*, still smaller; *d, d*, the smallest which could be detached.

globulins, which may be derived from muscle. This substance bears the same relation to living muscle that plasma does to living blood. By pressing muscle kept at a temperature below the freezing-point it is possible to obtain a viscid, opalescent fluid of alkaline reaction, which soon presents the phenomenon of clotting, and one has resulting a *muscle-serum* and *muscle-clot*. This muscle-clot is myosin. During the process the fluid becomes acid in reaction. The clotting of muscle-plasma is caused (probably) by ferment action, and the ferment (myosin-ferment) is derived from a composite antecedent, similar to fibrinogen, called *myosinogen*.

What gives muscle its red color?

Hæmoglobin of the blood in some degree; but there is also a distinct pigment known as *myohæmaturin*.

What is the chemical composition of muscle ?

Water is a chief ingredient, and myosin the characteristic one. Salts are found, chiefly of potassium. Various proteids, such as gelatin, elastic material, and albumins, are found, together with fats and extractives. The extractives are mostly complex organic compounds: among them may be mentioned kreatin, lactic acid, and sugar. Urea is not found, except in minute quantities, though it is regarded as originating from the waste products of muscular action. The following table formulates the proportion of these constituents:

Water	745
Solids:	
Myosin and insoluble proteids	155
Soluble proteids	20
Gelatin	21
Fats	23
Organic and inorganic salts	36
	<hr/>
	1000

What is the reaction of live muscle ?

Alkaline, due to the presence of potassium phosphate.

What is the function of the muscles ?

They contract and cause motion in the parts to which they are attached. During life the muscles are always tense, and this condition favors a more powerful action when the muscles contract in response to stimuli.

How do the muscles affect the blood passing through them ?

They abstract much of the oxygen and give off large amounts of carbonic acid, so that blood after circulating through the muscles, even when they are at rest, becomes very dark. It is probable that an abundance of oxygen is especially essential to the healthy condition of the muscles, and it is found that in an atmosphere of oxygen muscles retain their power of contraction longer than in one of hydrogen or carbonic acid.

What peculiar electrical condition is noticed in living muscle ?

When a living muscle is tested by means of the galvanometer after removal from the body, it is found to develop certain electrical currents known as *muscle-currents* or *currents of rest*. They are

strongest from the centre of the muscle toward the cut end, though certain minor currents are developed with the electrodes in closer proximity. The cut ends of a muscle are always electro-negative to its equator. This phenomenon cannot be observed in uninjured muscle when in the body, but any injury will render the injured portion electro-negative to the rest of the muscle. This condition ceases with the power of contraction, and cannot be demonstrated in dead muscle.

What is the effect of contraction upon this "current of rest"?

When the muscle is made to contract, the galvanometer needle, which has indicated the passage of an electrical current during rest, flies quickly back toward the zero indicating the cessation of the current of rest. This action is known as the *negative variation* of the galvanometer, and as soon as the contraction of the muscle has ceased the instrument again indicates the presence of the current of rest.

What is the cause of these electrical currents?

This is not yet fully determined, but they are probably due to chemical changes resulting from the physiological degeneration. It has been held that such currents occur naturally in muscle as the result of certain of the cells exciting electro-motive forces, but the former theory seems the more plausible.

What stimulus causes a muscle to contract?

The stimulus is supplied by the motor nerve which is distributed to the muscle.

How do the motor impulses reach the fibres?

The nerve divides and subdivides in the muscle until only a single axis-cylinder is supplied to a small group of muscle-fibres. This axis-cylinder then forms a delicate plexus about the muscle-fibres, and in the case of plain muscle-fibres ends in the nucleus of the fibre. In the striped fibres there is a special termination in a small granular mass called the *motorial end-plate*.

Is the property of contraction inherent in the muscle itself, or does it depend upon the nerve?

It is a property of muscle.

What artificial stimuli may be used to cause muscular contraction?

Certain stimuli may be applied to a muscle or to the nerve sup-

plying it which excite it to action. It is more usual to stimulate the nerve, as this is more convenient and more effectual. There are four kinds of excitants that may be used: 1, mechanical, as by a blow or prick or pinch; 2, heat, as by a hot needle; 3, chemical, as dilute acids, etc.; 4, electrical, as by the galvanic or faradic current. This is the most usual as well as most convenient kind of stimulus for experiment.

How are the phenomena of a contraction observed?

They are commonly observed in a tracing upon an instrument called the myograph, and usually a large muscle of a frog and its nerve are taken for the demonstration. The time of the observation is recorded by the vibrations of a tuning-fork. Such a preparation is known as "a nerve-muscle preparation," and the tracing obtained is called a "muscle-curve."

At what period of an electrical current do the muscles contract?

Only at the making and breaking. If a nerve-muscle preparation be arranged for experiment and stimulus be applied by means of a galvanic cell, it will be found that the muscle will contract only at the instant the circuit is completed and at the instant it is broken. During the time the current is *passing* no contractions of the muscle occur, unless the character of the current changes or the strength of the current is considerable. The mere passage of an electrical current does not cause a muscle to contract, but the *entrance* or *exit* of the current is the stimulus. It does not matter if the positive pole be applied to the nerve nearer the muscle, or if the negative pole is the nearer: the contraction is the same with an *ascending* as with a *descending* current.

Describe the phenomena observed in a single contraction following a stimulus.

There is a brief period during which no action occurs, the latent period, during which the stimulus applied to the nerve is being transmitted to the muscle. Then follows a sharp, sudden contraction of the muscle (stage of contraction), which is intensified steadily to a maximum, and then the muscle more slowly relaxes (stage of elongation), and the muscle returns to its former condition of rest. There are sometimes less violent contractions which follow, and are due to the elasticity of the muscle. The whole time consumed is about one-tenth of one second, and of this time

the latent period and the stage of contraction consume only about one-tenth each.

What is tetanus ?

When the stimuli follow one another in rapid succession the contractions are practically constant, and the stage of elongation does not follow. This condition is known as *tetanus*. The stimuli may be slow enough to allow perceptible quivering of the muscle (and a wavy tracing of the myogram), or may be very rapid, so as to keep the contraction constant.

What effect has fatigue upon the muscle ?

Its latent period is longer and the strength of the contractions diminish.

Is the temperature of muscle elevated by action ?

Yes. It has been estimated that the temperature of the biceps muscle may be elevated one to two degrees of the Fahrenheit scale by exercise. It is not known whether this is due to chemical action or to friction between the fibres.

How does the shape of the muscle change in contraction ?

The muscle becomes shorter, thicker, and harder, and seems to bulge at the centre. This is not an actual increase in bulk, for what is gained in thickness is made up in the loss by shortening. Each fibre of the muscle contracts and becomes short and thick, as does the whole muscle. This shortening is due to an approximation of the elements probably, and not to a change in the arrangement of the elements.

What chemical changes occur in muscle with action ?

The muscle (in rest alkaline) becomes acid from the development of lactic acid, and there is found a kind of glucose known as *inosite*, or "muscle-sugar." Besides this, the active metabolism increases the production of carbonic acid and of extractives.

What is rigor mortis ?

When a muscle is dead it will no longer respond to stimuli, but remains in a contracted state, fixing the limbs and body in rigid condition. This post-mortem rigidity constitutes rigor mortis. The muscles of the neck and jaw are usually first affected, and

then of the arms, gradually passing downward until the whole body is stiff. This begins usually soon after death, but may be delayed for several hours, and lasts until putrefactive changes have set in, when the body relaxes. All muscles are affected, plain as well as striped.

What is the cause of rigor mortis ?

Coagulation of the muscle-plasma.

What is the post-mortem rise of temperature ?

After death there is considerable rise of the temperature of the body, which is very marked during the progress of rigor mortis. It may amount to 5° or 10° F., or even more.

What changes occur in muscle after death ?

The muscles become set in contraction, and their reaction becomes acid from the development of lactic acid.

How do the voluntary muscles act ?

They act as the power which moves the bones in their function as levers. Each of the three classes of levers is illustrated in the body: (1) Fulcrum between power and weight: ham-string muscles acting upon the ischium to raise the body from a stooping position; hip-joint, fulcrum. (2) Weight between power and fulcrum: depressors of lower jaw acting against the tension of the temporals, etc., with temporo-maxillary articulation for fulcrum. (3) Power between weight and fulcrum: biceps of the arm in raising the forearm, with elbow-joint as fulcrum.

How do the involuntary muscles act ?

They do not have attachments to the hard parts, but enter into the composition of the walls of hollow organs which require elasticity and variation in size. The heart and arteries, as well the digestive tract, furnish numberless examples of their action. They are often rhythmical in their action (peristalsis), and the stimulation of this class of muscles does not cause a tetanus (except the heart), but a succession of alternate contractions and relaxations.

NUTRITION.

What is nutrition ?

By nutrition we mean the physiological principles which preserve the normal conditions of the structure and function of the body, so

far as refers to the balance between the income and outgo of material. While it is almost an impossibility to study this subject exactly, yet an idea of the modes of expense and income may be gained by consideration of data which are tolerably fixed. In considering the income and expenditure of the body it is always necessary to bear in mind that all the factors are variable and the results inconstant, for the income often exceeds the expense, and *vice versâ*, in life.

What are the daily expenditures of the body?

The more important are those by the ordinary excretory channels—lungs, skin, kidneys, and intestines.

From the lungs there are exhaled every twenty-four hours—

Of carbonic acid, about	30 ounces.	
Of water	10	" 40 ounces.
Traces of organic matter.		

From the skin—

Water	23	"
Solid and gaseous matter	1 ounce.	24 "

From the kidneys—

Water	50 ounces.	
Organic matter	1½	"
Minerals and salines	½ ounce.	52 "

From the intestines—

Water	4 ounces.	
Various organic and mineral substances	2	" 6 "

Total, 122 ounces.

What are the sources of income?

Food and drink and oxygen are the factors of the income, and may be calculated about as follows for twenty-four hours:

Food (chemically dry)	16 ounces.
Water (as drink and as combined with solid food) .	80 "
Oxygen (absorbed by lungs)	26 "
Total,	122 ounces.

Thus we may represent the schematic plan of income and ex-

pense as about equal, but it must be borne in mind that the plan only represents an average result of both.

How are variations in the rate of income and expenditure shown?

By changes in the bodily weight.

What is the result of the expenditure?

(1) The *growth* of the body and secretion of its necessary materials, as well as the *maintenance* of the tissues, subjected as they are to the wear incident to the continuance of life and function.

(2) The continuance of physical conditions suitable to life in the form of heat and motion. The actual combustion of carbon (*i. e.* oxidation) must be sufficient to maintain the animal heat and the nourishment of the muscles upon which the continuance of life depend.

(3) Nervous energy, as in the regulation of all physiological processes by the reflexes, as well as in voluntary mental and nervous action.

What is the amount of energy resulting from the bodily expenditure?

The daily work of the body has been calculated to be about 3400 foot-tons. Of this about one-tenth has been considered to be exhausted in involuntary muscular action (circulation, respiration, etc.) and in voluntary motion, while the remainder (nine-tenths) is expended in maintaining the body-heat. Another method of considering this enormous force may be of use: it is equivalent in heat to that required to raise nearly 50 pounds of water from the freezing to the boiling-point, or in mechanical force it is sufficient to raise the body of a man weighing 150 pounds to a height of 8½ miles.

Does this calculation include all the energy developed in the body?

No. It takes no account of energy exerted in nervous manifestations, nor does it take into consideration the utilization of the heat absorbed by the body.

What is "nitrogenous equilibrium"?

When an animal is fed exclusively upon a nitrogenous diet, it is found that after a time the egested nitrogen approaches and finally balances that taken in as food. This is known as the "nitrogenous

equilibrium." But at the same time the animal may increase in weight, and this occurs by the formation of fat which is stored up in the tissues. The nitrogenous equilibrium is more easily maintained by the addition of carbohydrates to the food.

What is the effect of starvation upon the body?

There is a loss of weight in all the tissues, but it is in the loss of the fat that the change is most marked: the fat almost entirely (93 per cent.) disappears after death from starvation. The sense of hunger gives way to a sense of pain; thirst is excessive; sleep is absent; progressive weakness accompanies increasing emaciation; the exhalations of the skin and lungs are foetid; and diarrhœa with convulsions or delirium often precedes death. Death occurs with absolute deprivation of both food and drink at the end of about a week (six to ten days), though life may be considerably prolonged by small quantities of food or water. The temperature of the body falls before death very considerably (30° C.), and it has been considered that death resulted from cold, no fuel being furnished to maintain animal heat. The body decays rapidly after death from starvation.

What is the effect of an exclusive diet?

The result of feeding animals exclusively on a single article of diet (sugar, gum, oil, etc.) is practically the same as that of starvation, except that death does not occur until the end of four or five weeks. In man the exclusive diet of isolated communities often results in the breaking down of tissue and general malnutrition.

What is the effect of over-feeding?

An excess of nitrogenous food, if digested, increases the metabolic work of the glandular organs (especially of liver and kidneys), and induces disease in those organs and faulty excretion of nitrogenous matter. This may be obviated or delayed by active physical exercise. Carbohydrate food in excess is stored up in the form of fat, which may be excessive, with resulting fatty infiltration of the viscera, or it may show as glycosuria.

An excess of any food is apt to pass undigested through the intestines and undergo putrefactive changes, with resulting gaseous

distension: the carbohydrates are especially apt to give rise to this disturbance.

What are the requirements of a normal diet?

There should be a general diet of well-cooked food, and it should contain about the amount of carbon and nitrogen which is excreted; that is, it should maintain an equilibrium. This is, commonly, about two pounds of solid food and two quarts of fluid. The proportion of the various kinds of foods varies considerably, but in a general way for a healthy man one may divide the solid food somewhat in this way: nitrogenous food (meat), about $\frac{1}{2}$ pound; hydrocarbon and fat-food (bread, vegetables, and butter), about $1\frac{1}{2}$ pounds. Besides this, the food will contain from 1 to 2 ounces of salts and a varying amount of sugar.

NERVOUS SYSTEM.

THE NERVES.

What are the elementary tissues of the nervous system?

Nerve-fibres and nerve-cells. The fibres are of two kinds, and are united in bundles to form nerve-trunks or nerves. The cells are collected in groups and form the nerve-ganglia, but the nerve-fibres are also found in the ganglia.

What varieties of nerve-fibres occur?

1, The medullated or white fibres; 2, the non-medullated or gray fibres.

Describe the medullated or white fibres.

These fibres consist of an external nucleated sheath or neurilemma which is made up of (1) a layer (Fig. 22) of endothelial cells which surround and invest; and (2) an inner protective *medullary sheath* (the white matter of Schwann). Within these is (3) the axis-cylinder, which consists of a number of the primitive fibrillæ of the nervous tissue. In size these fibres vary considerably, but the average may be said to be about $\frac{1}{1500}$ inch in diameter.

FIG. 22.



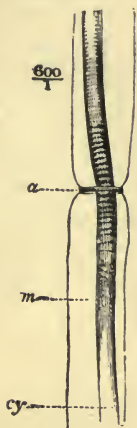
Diagram of
Structure of
Nerve-fibre.

What are the nodes of Ranvier?

They are constrictions which occur here and there in the course

of the white fibres. These constrictions (Fig. 23) are of the external sheath, and break the continuity of the medullary layer.

FIG. 23.



Nerve-fibre from the Sciatic Nerve of the Rabbit, after the action of nitrate of silver: *a*, ring formed by thickened membrane of Schwann; *m*, white substance of Schwann rendered transparent by glycerin; *cy*, cylinder-axis, which just above and below the level of the annular constriction presents the striæ of Frommann.

Is the axis-cylinder broken at the nodes of Ranvier?

No. The axis-cylinder is continuous from one end of the nerve-fibre to the other.

Describe the non-medullated fibres.

They consist of the axis-cylinder alone, without the medullary layer. They do not differ in any other regard from the white fibres. When collected in bundles to form nerves they have a yellowish or grayish color. They are found in the olfactory and auditory nerves and in the nerves of the sympathetic system, and they occur in greater or less number in the nerves of the cerebro-spinal system. In size these fibres are about one-third to one-half the diameter of the medullated. They are sometimes spoken of as the *fibres of Remak*.

What change occurs to the white fibres near their termination?

The medullary layer disappears and the axis-cylinder continues with the neurilemma; but this too disappears before the final ending of the fibre in the tissues. The fibre then splits into two or more terminal branches; that is, the white fibre becomes a non-medullated fibre.

How are the fibres united to form nerves?

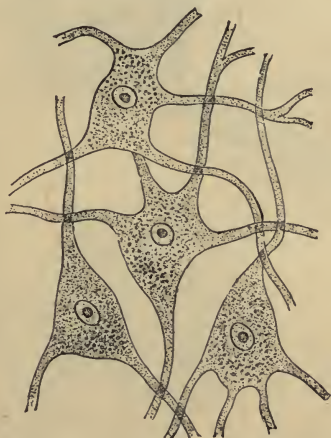
The fibres are joined in bundles which are enclosed in a thin fibrous sheath (perineurium), and these bundles of nerve-fibres are bound in a firm connective tissue which serves to protect and to unite them strongly.

What are the characteristics of nerve-cells?

Nerve-cells or ganglion-cells present a great variety of shapes, and yet have common characteristics. The cell-body is granular and contains a large nucleus which contains a prominent nucleolus. The cells have at least one process, and often more (Fig. 24), and

the cells are classified as unipolar, bipolar, or multipolar. These processes are of two kinds—one kind dividing and subdividing (*branching processes*) until they become very delicate and seem to

FIG. 24.



Nerve-cells from the Anterior Horn of Gray Substance of the Spinal Cord.

join with the equally fine processes from other cells; another class (*axis-cylinder processes*) pass on without division, and become axis-cylinders of medullated nerve-fibres.

The nerve-cells vary greatly in size, and are very diverse in form, but the presence of nucleus and nucleolus and of the processes is characteristic of nerve-cells. They may be enclosed in a delicate capsule which becomes continuous with the neurilemma (Fig. 25).

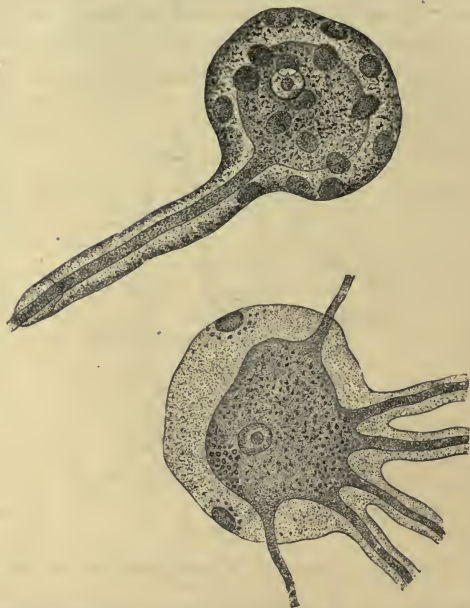
What is the function of the nerve-fibres?

The transmission of a stimulus. The axis-cylinder connects the centre and periphery cells, and conveys between them the stimuli. This transmission for any particular fibre is in one direction only.

How may the nerve-fibres be classified?

Into *afferent* (or *centripetal*) and *efferent* (or *centrifugal*) fibres.

FIG. 25.



Nerve-cells, from Spinal and Sympathetic Ganglia of Man, enclosed in their Capsular Sheaths—from hardened preparations (Key and Retzius).

The former are those by which impressions are taken from the periphery to the brain, and are commonly called *sensory* fibres. The latter conduct the stimuli to the periphery, and are known as *motor* fibres. Besides these, some of the fibres serve to connect ganglia of the central system one with another, and these are known as *intercentral* fibres.

What modifications of function belong to the afferent nerves?

The direct function of the centripetal nerves is the conduction of an impulse which gives rise to a sensation, as of pain or heat; but beyond this we may have a reflex or an inhibitory impulse conducted.

What modifications of function belong to the efferent nerves?

The centrifugal nerve-fibres may carry other than motor im-

pulses: they control nutrition (trophic nerves) and secretion (secretory nerves), and they may also increase or check other efferent impulses.

What is the velocity of the transmission of impulses?

Efferent impulses are somewhat slower than afferent, the rate for the former being about 110 feet-per second, for the latter about 150 feet.

What are "personal error" and "personal equation"?

The time occupied in executing a voluntary movement at a given signal—for instance, the recording the time of a transit in an astronomical observation—is found to be sufficient to demand a correction for an accurate result. This amounts to $\frac{1}{4}$ to $\frac{1}{50}$ of one second with different individuals. The time lost in this way is known as the *personal error* of the observer. When this has been ascertained by experiment, the allowance to be made for the personal error is his *personal equation*. This remains nearly constant for each person.

How do the sensory nerves terminate at the periphery?

The sensory nerves ending in the skin find their way to certain bodies (sense-organs) which are essential to the conduction of the sensory impression to the central nerve-ending. These sense-organs are of several kinds. In the fingers and toes are found two kinds of sense-organs which may be especially mentioned: 1, touch-corpuseles; 2, Pacinian corpuseles. The anatomy and physiological use of these bodies are still somewhat obscure; and, indeed, the whole subject of sensory nerve-terminations is but illy understood. We may regard the fibres of sensory nerves, as a majority, to form a minute plexus in the corium and to terminate in sense-organs in a way not known. Some of the special sense-organs are possessed of nerve-endings which are more clearly observed.

What two sets or systems of nerves do we possess?

The cerebro-spinal and sympathetic.

What constitutes the cerebro-spinal system?

The brain, the medulla oblongata, and the spinal cord, with the nerves proceeding from them.

What constitutes the sympathetic system?

Primarily, the sympathetic system consists of a double chain of

ganglia and communicating nerves which lie on either side of the vertebral column and extend throughout its entire length. Other ganglia occur in connection with some of the cranial nerves, more especially the vagus and trigeminus. There are ganglia and plexuses connected with the various organs (*e. g.* cardiac and solar), and still others in the substance of some of the organs (*e. g.* stomach and intestines). The sympathetic system has numerous communications with the cerebro-spinal system.

What is a reflex action ?

An action which results from a centripetal nerve-impulse passing to a nerve-centre in a ganglion, and there transforming to a centrifugal impulse passing to a muscle. Such an action may be simple and involve a single muscle, or complex and involve many: thus, a ray of light falling upon the retina causes a simple reflex contraction of a single muscle, and the iris contracts. As an illustration of a complex reflex action, however, irritation of the larynx causes not only a closing of the glottis, but a contraction of all the muscles involved in forced expiration or coughing.

Are all reflex actions involuntary ?

Yes, but many of them may be checked or prevented by a voluntary effort.

Do the reflexes depend upon the cerebro-spinal nervous system or upon the sympathetic ?

They are more noticeable in the cerebro-spinal system, but they may belong to either, or may be mixed, the impulse going by the one system and returning by the other. Examples: sneezing, coughing, swallowing are cerebro-spinal reflexes; the vaso-motor reflexes are largely sympathetic, but the centripetal nerve is often cerebro-spinal, as in the secretion of saliva or in blushing.

What relations exist between the stimulus and the resulting reflex ?

A stimulus which is mild causes a reflex of the muscle of the same side, but as the stimulus is increased the muscles of the opposite side may be involved, the reflex of the irritated side remaining the stronger. As the irritation is increased the reflex involves more muscles; that is, the stimulus spreads to a greater number of cells in the ganglion and more efferent fibres are involved. These relations are obtained largely by experiments upon decapitated frogs.

What are acquired reflex actions?

A reflex action which is as strong in an infant as in an adult (the contraction of the pupil in the presence of light) is a *primary* reflex. Another class of reflex actions require frequent repetition before they are automatically performed, and such actions are called *acquired* reflex actions, as walking, reading, etc.

What is automatic action of nerve-centres?

There are certain actions which continue, and, while they are closely related to reflex action, do not seem to be reflexes, but to originate in the part. Thus, the peristaltic action of the alimentary tract is not dependent upon the presence of food in the intestines, but may be excited in the absence of food or checked when it is present. The action has been referred to small ganglia and nerve-plexuses found there (Auerbach's and Meissner's), and is considered to originate in the local nerve-centres. This is what is known as automatism or automatic nerve-action.

What power of inhibition and augmentation of action has the nerve-centres?

In speaking of the action of the heart it was shown that certain fibres of the vagus nerve check the heart's action, and certain other fibres increase it. This control of the action of organs is not confined to the heart, but similar power of regulation belongs to the nervous centres for many other organs.

SYMPATHETIC SYSTEM.

How is the sympathetic nervous system arranged?

It is arranged in ganglia and plexuses. It is intimately connected with the cerebro-spinal system by communicating branches from each spinal nerve and many of the cranial nerves.

What is a ganglion?

It is a collection of gray and white nerve-substance, which is usually oval in outline, and is frequently found in the course of a nerve-trunk. In the sympathetic system the ganglia contain numerous nerve-cells, smaller than those of the brain and spinal cord, and from these cells arise nerve-fibres which distribute themselves in the plexuses.

What peculiarities have the fibres of the sympathetic nerve?

They are often smaller than those of the cerebro-spinal system,

and there are in the nerves a considerable number of non-medulated fibres—more than in the spinal nerves.

Do the sympathetic nerves differ materially from the cerebro-spinal?

No. They are very similar. The occurrence of ganglia upon the sensory branch of the spinal nerves and upon the sensory cranial nerves (pneumogastric, glosso-pharyngeal, and trigeminus) adds to the similarity. Then, too, the frequent communications between the two systems practically makes one system of them, and the division is largely one for convenience.

Is the sympathetic system dependent upon its connection with spinal axis?

• Yes.

Where are the functions of the sympathetic system most shown?

In the organs of nutrition and secretion and in the vascular system.

What are the sympathetic ganglia in the head?

They are four in number—ophthalmic, sphenopalatine, submaxillary, and otic ganglia. Each has communications from the general sympathetic, and from the cranial nerves both motor and sensory fibres.

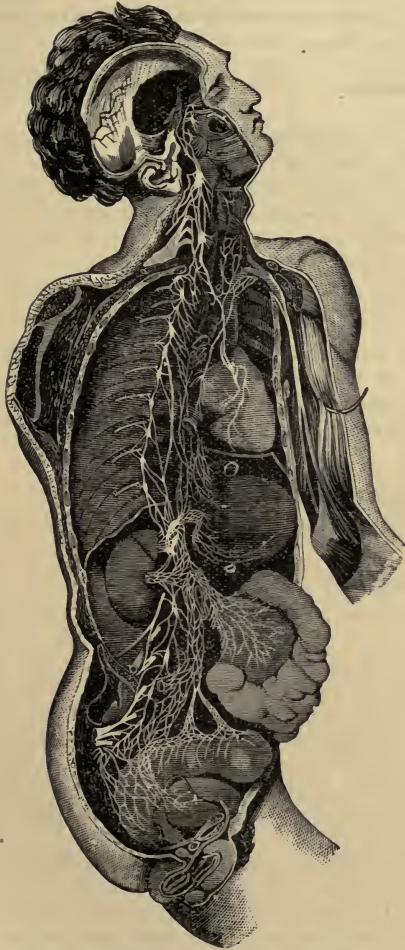
Describe the ophthalmic ganglion.

It is a small ganglion situated in the orbit, and receives communications from the sympathetic and from the motor oculi (third) nerve, a motor branch, and from the trigeminus (fifth) nerve a sensory branch. Its branches pass into the eyeball (ciliary nerves), and are distributed in the iris. Their function is the control of the pupil, of the apparatus of accommodation, and of the vaso-motor function in the vessels of the eye.

Describe the sphenopalatine ganglion.

It is situated in the sphenomaxillary fossa, and receives branches from the cervical sympathetic system and motor fibres from the facial (seventh) nerve, and sensory from the fifth. Its branches are distributed to the mucous membrane and muscles of the palate and uvula, and to the nasopharynx. They are both sensory and motor.

FIG. 26.



Ganglia and Nerves of the Sympathetic System.

Describe the submaxillary ganglion.

It lies in close proximity to the submaxillary gland. It receives

branches from the superior ganglion of the neck and a sensory branch from the lingual branch of the fifth nerve. Its motor branch is through the chorda tympani nerve from the seventh or facial nerve. Its branches are distributed to the submaxillary gland and control its function.

Describe the otic ganglion.

It is a small ganglion lying upon the third division of the fifth nerve as it emerges from the foramen ovale. It has branches from the sympathetic on the middle meningeal artery, and both a motor and a sensory communication from the fifth, as well as a branch from the glosso-pharyngeal through Jacobson's nerve. Its branches are motor, to the tensor palati and tensor tympani muscles; and sensory, to the mucous membrane of the tympanum and Eustachian tube.

How does the sympathetic system in the trunk communicate with the spinal nerves?

From each spinal nerve is given off a communicating branch to a neighboring ganglion. These branches contain both motor and sensory fibres.

How are the ganglia classified?

Into cervical, thoracic, abdominal, and pelvic ganglia and plexuses.

Describe the cervical ganglia.

There are two—a superior and inferior (with sometimes a third, middle)—ganglia on each side (Fig. 26). These ganglia receive communications from each of the cervical spinal nerves and from each other. Their branches are given off to form (1) the *carotid plexus*, which follows the carotid artery and its branches. It forms by its inosculations the vaso-motor plexuses of the arterial system, and furnishes branches for distribution to the thyroid gland, larynx, trachea, pharynx, and œsophagus. (2) It furnishes the *cardiac nerves*, which are distributed in the cardiac plexus.

What is the distribution of the thoracic ganglia?

In the chest the ganglia are numerous (Fig. 26), and each ganglion receives two branches of communication from the intercostal nerve above it, while the relationship of the ganglia is maintained by the intercommunicating chain. The nerves originating here are distributed to the plexuses on the thoracic aorta, and to those of the lungs and œsophagus.

Describe the abdominal sympathetic.

In the abdomen the sympathetic consists mainly of an aggregation of ganglionic enlargements situated upon the celiac artery, known as the semilunar or celiac ganglion. It communicates with the thoracic ganglia and with all the lumbar nerves. From this centre proceed a multitude of diverging and inosculating fibres, which, from their common origin and radiating course, are called the *solar plexus*. Its secondary plexuses, accompanying the branches of the abdominal aorta, are distributed to the stomach, intestines, spleen, pancreas, liver, kidney, and internal organs of generation.

How are the pelvic plexuses derived?

From four or five pairs of ganglia situated on the anterior portion of the sacrum and terminating in the *ganglion impar*, lying upon the coccyx. Its fibres join those from the solar plexus, and are distributed with them along the course of the branches of the internal iliac arteries.

Describe the sensibility and motor influence of the sympathetic nerves.

It will be remembered that the spinal nerves, both afferent and efferent, act very quickly upon the tissues supplied by them; the sympathetic nerves act more slowly. Thus, if the afferent nerve or a ganglion or its efferent nerve be stimulated, there is a slow wave-like series of motions set up in the parts supplied, which continue for some time after the stimulus is withdrawn. This is particularly well seen in the intestinal peristalsis which may be excited by stimulation of the intestine or of the semilunar ganglion or of the branches of the solar plexus.

What is the effect of the sympathetic nerves upon special senses?

The dilatation of the pupil is effected through it, and probably the accommodation is acted upon by fibres other than the oculomotorius, which come through the lenticular ganglion. The tensor tympani muscle is supplied from the otic ganglion.

What is the vaso-motor function of the sympathetic?

The muscular coats of the blood-vessels, especially of the arteries, are under the control of the sympathetic filaments and plexuses, which accompany them throughout their entire system. These fibres are of two kinds as regards their function: (1) vaso-constrictor and (2) vaso-dilator fibres.

How do the vaso-motor fibres arise?

They probably arise from spinal centres, and are controlled in some way by the vertebral ganglia of the sympathetic system. The vaso-dilator fibres are not to be distinguished as such, though their presence is inferred from the action of special nerves. For example, the stimulation of the chorda tympani nerve has a vaso-dilator effect in the submaxillary gland. The inhibitory and augmentary effects of the cardiac nerves are similarly carried by or through sympathetic plexuses.

Do the visceral sympathetic nerves have a similar central origin?

Yes, but they too are acted upon by the ganglia through which the fibres pass, and in which new nerves arise from the nerve-cells.

What control has the sympathetic system over the secreting glands?

There has been demonstrated in some of the secreting glands—and it is probably true for all—that functional stimuli, distinct from the vaso-motor, come through the sympathetic nerves, and that these fibres are closely associated with the vaso-motor fibres. Thus, in the stomach the secretion of the gastric juice is only temporarily suspended by the section of the vagi, and is resumed by the action of the sympathetic, showing that the control is by the sympathetic.

What is "arrest of action"?

It is a temporary check upon the control of an organ by the sympathetic system, which check comes through the cerebro-spinal system. Such an action is frequent in the control of the glandular organs, and usually is shown in the dilatation of the capillaries through the arrest of the action of the vaso-motor nerves in response to a sensory reflex. It is also seen in the sphincters, which keep up a condition of tonic contraction to close the orifices of the body, but relax in response to an impulse from the proper centre. The sphincter ani in this way retains its hold upon the intestinal orifice until the centre in the cord permits an arrest of action and relaxation of the muscle.

SPINAL CORD.**Describe, roughly, the spinal cord.**

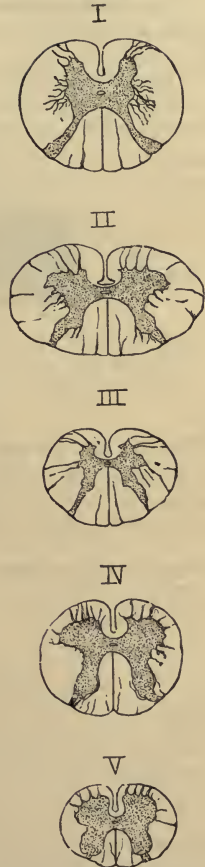
The spinal cord is that portion of the cerebro-spinal nervous sys-

tem contained within the spinal canal. It connects with the brain through the medulla oblongata, and terminates in a fine thread of gray matter (the filum terminale) at about the second lumbar vertebra. In form it is irregularly cylindrical, and varies in the size and shape of its cross-section at various levels, as is shown in Fig. 27. It is incompletely divided into symmetrical halves, and its mid-line is indicated in front by a fissure (anterior median fissure) which extends for about one-third its antero-posterior diameter; behind by a deeper but narrower fissure (posterior median fissure), which involves about one-half of the same diameter. It is composed of white and gray substance.

How are the white and gray matters arranged in the spinal cord?

The white substance is arranged externally to the gray in each half of the cord, and is so disposed as to be conveniently divided for purposes of description into three columns, known respectively as the anterior, lateral, and posterior columns of the cord. There is also a thin band of white substance at the base of the anterior median fissure (the white commissure). The gray matter fills in the central portion of the cord, and is variable in its amount, the calibre of the cord at its enlargements being increased by the increase in the amount of gray matter at these points (Fig. 27). The white substance will be noticed to diminish quite regularly in the sections of the cord from above downward, as seen in this series. The gray substance is not completely halved by the anterior and posterior fissures of the cord, but is continuous across the mid-line; and in it at the centre is a minute canal communicating with the ventricles of the brain. The gray matter is more abundant between the lateral and anterior and between the

FIG. 27.



Transverse Sections of the Spinal Cord in Man: I, upper cervical region; II, lower cervical region; III, dorsal region; IV, lumbar enlargement; V, lower extremity.

lateral and posterior columns of the white substance, and the names anterior and posterior horns (cornua) are given to these regions respectively.

What are the nerve-roots of the cord ?

Issuing from the cord along its course are thirty-one pairs of nerves. Each of these spinal nerves is made up of an anterior and a posterior root (Fig. 28), of which the latter is the larger.

FIG. 28.



Transverse Section of the Spinal Cord: *a*, *b*, spinal nerves of right and left sides; *d*, origin of anterior root; *e*, origin of posterior root; *c*, ganglion of posterior root.

The anterior root arises between the anterior and lateral white columns, the posterior between the posterior and lateral columns. On each posterior nerve-root is found a ganglion immediately beyond its point of emergence. The function of this seems to be trophic.

What is the minute structure of the white substance ?

It is found to be made up of medullated nerve-fibres, which collect to form the anterior and posterior nerve-roots, and communicate with other regions of the cord.

What is the minute structure of the gray matter ?

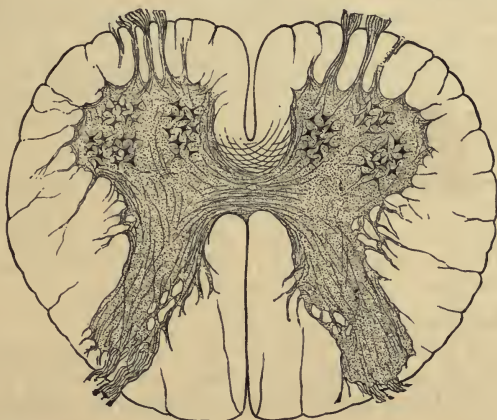
The gray matter contains multipolar cells of varying size and shape, with axis-cylinders and "branching" processes lying in the neuroglia (connective tissue). The multipolar cells are some of them quite large. In the anterior horn of the gray substance the axis-cylinder-processes of the nerve-cells connect directly with fibres forming the anterior nerve-roots (Fig. 29); but in the posterior cornu the communication is through the branching processes joining the divided axis-cylinders of the posterior nerve-roots, forming thus a minute plexus known as Gerlach's nerve-network.

Whence are the fibres derived which make up the nerve-roots ?

(*a*) Anterior nerve-roots are derived from (1) the anterior columns of the cord, but some fibres come through the commissure from (2) the opposite side, and some come from (3) the lateral tract. Still other fibres arise from (4) the multipolar cells in the anterior cornu of the gray matter. The fibres of the anterior nerve-roots are efferent or motor fibres.

(b) Posterior nerve-roots enter into the posterior horn of the gray matter, and the fibres break up to form Gerlach's network, communicating with the large multipolar cells, but some fibres

FIG. 29.



Transverse Section of the Spinal Cord in Man (lumbar region).

cross through the gray commissure to the opposite side. The fibres of the posterior roots are afferent or sensory fibres.

If the anterior nerve-roots be cut, what is the result?

The anterior nerve-roots are efferent or motor; therefore their division results in complete loss of motion in the parts supplied. If the distal portion of the cut nerve-root be stimulated, muscular action follows, while irritation of the proximal portion produces no noticeable effect.

What follows division of the posterior roots?

Loss of sensation without loss of motion. Stimulation of the distal portion of the cut posterior root produces no result, either in sensation or motion. Irritation of the proximal end will, however, cause very acute pain.

Is the course of the fibres through the spinal cord known?

No, not fully. Certain fibres have been traced with fair accu-

racy through their length, notably fibres to the arm (direct pyramidal tract) in the anterior column, and to the leg (crossed pyramidal tract) in the lateral column.

Do all the fibres of the spinal nerves pass from the brain through the spinal cord?

No. It has been calculated that only about one-half as many fibres enter the spinal cord from the brain as leave it through the nerves; therefore it must follow that some fibres originate from the cord. The increase in gray matter in the cervical and lumbar enlargements, where the fibres for the large plexuses of the nerves (brachial and lumbar) are given off, confirms this view.

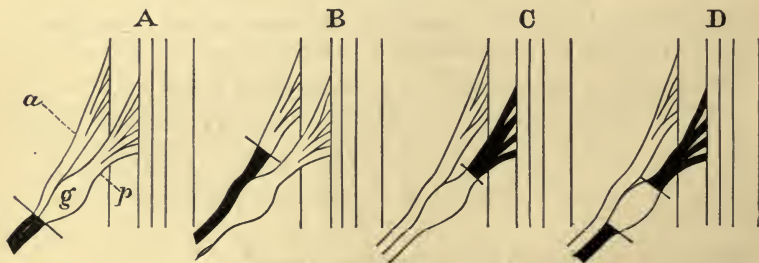
Where are the trophic centres for the anterior nerve-roots?

The posterior nerve-roots, we have seen, seem to be dependent upon the ganglia which are found upon them for trophic influence. The anterior root in a similar way seems to depend upon a trophic centre in the gray matter in the anterior horn.

What is degeneration of a nerve-fibre?

Division of a nerve is followed by a degeneration or breaking down of the axis-cylinders of its fibres within a day or two, the loss of function being an earlier and immediate manifestation. This

FIG. 30.



Degeneration of Spinal Nerves and Nerve-roots after Section: A, section of nerve-trunk beyond the ganglion; B, section of anterior root; C, section of posterior root; D, excision of ganglion; a, anterior root; p, posterior root; g, ganglion.

degeneration is centrifugal; that is, does not proceed toward the spine, but to the periphery. If the posterior root be cut, however, between its ganglion and its emergence from the cord, the degeneration is toward the cord—*i. e.* centripetal—and the nerve

beyond the ganglion does not degenerate. The anterior root cannot, however, be divided at any point beyond its emergence without centrifugal degeneration of the fibres (Fig. 30). The regeneration takes place slowly if the continuity of the nerve is at once restored, and may even follow after the nerve has degenerated for some months and a complete loss of function has affected the part supplied by it. The fact that the axis-cylinders are restored only in this way is of interest, as showing the influence of the trophic centres on the nerve-growth.

What are the functions of the spinal cord?

(1) The *conduction* of impulses from the nerves to the brain and from brain to nerves, and (2) the origination of action in response to stimuli from the periphery—*i. e. reflex action*.

Explain the action of the cord as a conductor of nervous impulses.

Than by the spinal cord there is practically no other nervous communication between the brain and the musculo-cutaneous system; hence through it must come all the nerve-impulses which pass to or from the brain. In other words, every sensory impulse that is *felt* and every motion that is *willed*, perception and volition being attributes of the brain, must be conducted through the nerve-fibres of the spinal cord to the brain, and *vice versâ*. No better illustration need be used than the abolition of both motor and sensory function which follows a cerebral apoplexy: the nerve-centre being destroyed, voluntary action and perception of sensation are lost, and yet the reflex response is prompt, showing that the brain-function is necessary in the chain of phenomena. Again, the same paralysis follows the section of the cord, and we must acknowledge their mutual dependence.

Does the gray substance act as conductor?

No, not when directly stimulated. The conducting fibres seem to be in the white columns, and each portion contains fibres which always conduct the same kind of impression.

What is the course of sensory impulses in the spinal cord?

This is somewhat problematical, but certainly these impulses enter the cord by the posterior nerve-roots. The fibres conducting them break up to form Gerlach's network, and cross to the opposite side of the cord through the gray commissure. It is probable that after decussating the fibres communicate with multipolar cells, and

thus pass on as white fibres in the lateral columns. These fibres enter the lateral columns (of the opposite side), and pass to the medulla as a distinct tract—the antero-lateral ascending tract—at the periphery of the lateral, extending into the anterior column.

What sensations are transmitted by this set of fibres?

It is by this tract that sensations of *pain* and of *temperature* are supposed to pass. There are also afferent fibres in the posterior columns—the posterior median—by which the sensations of *touch* and *weight* (or muscular sensation) are believed to pass; the latter, however, does not decussate. To recapitulate: sensations of pain and temperature are transmitted through the lateral columns, and those of touch and weight in the posterior columns.

What is the path of the motor impulses?

As has already been seen, these fibres are better demonstrated than the sensory. Most of the motor fibres cross to the opposite side in the medulla oblongata (decussation of the pyramids), and the impulses pass down by the lateral columns in the crossed or lateral pyramidal tract on the side opposite to that in which they originate. There is also a set of motor fibres which do not cross, but pass directly to the same side in the anterior columns, and decussate in the anterior or white commissure near the point of distribution. The destination of these fibres is variable, for the reason that the amount of decussation in the medulla is not constant; but, as a rule, the fibres in the direct tract go to the upper portion of the body.

Do the motor tracts carry only the fibres arising from the brain?

No. The cells in the anterior cornu of the gray matter of the cord originate many of the fibres which go to the nerves. This is demonstrated after division of the cord by stimulating these fibres: a series of co-ordinated motions follows, and this stimulus may be applied direct to the fibres or through the sensory nerves.

If one lateral half of the cord be cut through transversely, what are the results?

1. *Motor*.—There will be paralysis of motion of one-half the body below the section; and the paralysis will be of the same side if the section be below the decussation in the medulla; if it be above, the paralysis will cross to the opposite side.

2. *Sensory*.—Anæsthesia of the opposite side below the section,

and the loss of sensibility will be complete. At the same time, on the *same side* as the section the sensory function may be exaggerated, and there may be *hyperæsthesia* to such a degree that even a touch may cause exquisite pain.

What results follow electrical stimulation of the posterior columns of the cord?

If stimuli be applied to the posterior columns of the cord by a galvanic current, signs of sensibility are shown in the reflex actions; but it is only near the nerve-roots that the sensibility seems very marked. The intensity of the response increases with the strength of the current.

What reaction follows a similar stimulation of the anterior columns.

Motion in the parts below, and the motion is of a convulsive character. No pain seems to accompany the convulsive contractions of the muscles.

What is the effect in the lateral columns?

The stimulation of the anterior portion results in motion, which gradually decreases as one approaches the posterior nerve-roots, and then merges into the signs of sensibility similar to those excited by stimuli applied to the posterior columns.

What practical lesson does this impress?

That inflammatory changes in the meninges of the posterior portion of the cord excite pain, while meningitis of the anterior portion excites convulsions.

What important function, besides conduction, does the spinal cord perform?

The origination of motion in response to stimuli, or *reflex action*.

What difficulties present themselves in the study of the reflex function of the cord in mammals?

The great shock which follows injury of the spinal cord in mammals renders the study of its function difficult. It is sometimes hours, or even days, before any experiments can be conducted after the division of the cord in a warm-blooded animal, because of the failure of the reflexes to act; and when they do act the amount of degeneration which has followed the operation is uncertain. Cold-blooded animals (especially the frog) are used largely in such

experiments for this reason, and it is probable that in them there is a greater degree of this kind of response, though of the same nature as in mammals.

How are the reflex actions of the cord classified?

Into cutaneous and muscular reflexes.

What are cutaneous reflexes?

Muscular actions which follow gentle stimuli applied to the skin. The plantar reflex, or the motion of the toes and foot which occurs on tickling the sole of the foot; the cremaster reflex, or retraction of the testicle by contraction of the cremaster when the inner side of the thigh is stimulated; and the pupillary reflexes, contraction of the pupil to the stimulus of light,—belong to this class of cutaneous reflexes.

What are muscular reflexes?

Muscular actions which follow a slight blow upon a muscle or tendon when the muscle is in more or less tension. The patellar reflex is a well-known example of this form of action: if the knee be flexed to a right angle and the leg allowed to hang loosely, the quadriceps femoris muscle is made moderately tense. A gentle tap upon the tendon of the muscle below the patella will cause the muscle to contract and the leg to be more or less extended. These reflexes are sometimes called *tendon reflexes*.

What is inhibition of reflex action?

The ability to control or modify reflex action by an effort of the will or by mental action which is not consciously voluntary. As an example of this, if the palm of a sleeping child be touched by the finger, the baby's hand will grasp the finger; but if the child is awake, no such reflex occurs, but is checked by mental action. Again: one may avoid crying out when in pain by an effort of the will, or may hold the feet still when the soles are tickled.

Are reflex actions frequent in the ordinary acts of life?

They are. An ordinary act which has become habitual—for example, walking—while at the first it is performed as a voluntary muscular act, becomes reflex and is performed without conscious control of the mind, and is more easily and more gracefully done when no attempt is made to direct the actions of the muscles involved.

Do the reflexes vary in strength with the strength of the stimuli?

A strong stimulus will excite a stronger reflex than a mild one. A pin-prick will cause the foot to react more violently than tickling the sole. In certain diseases and after certain poisons these actions become very much exaggerated: tetanus and strychnine-poisoning put the cord in such a condition that a very slight skin-irritation may throw the entire body into a violent convulsive condition. Again, other diseases or drugs decrease the irritability of the cord.

What are special centres for reflex action?

Certain actions are automatic—that is, may take place without intervention of the will in response to special stimuli—and these actions are dependent upon certain nerve-centres in the cord. These centres have to do, noticeably, with sphincter action in the pelvic region, and the centres themselves are located in the lumbar region of the cord. To enumerate some of the automatic actions of these centres is sufficient, as they are all dependent upon special stimuli and special centres acting upon muscles peculiar to the act. They are defecation, micturition, emission of semen, erection of the penis, parturition. There are numerous other automatic actions besides those of the pelvic sphincters, but the mode of operation is well illustrated by these functions.

What other automatic action occurs in the spinal nerve-centres?

Vaso-motor centres and sweat-control centres are in the cord, and centres which control the nutrition of the muscles, as well as keep them tense in readiness to contract effectively; that is, maintain the *tone* of the muscles. The nutrition of the entire body is dependent upon the maintenance of this automatic control of the vaso-motor function, as is shown by the disorders of the skin and of the bones and joints which follow spinal injury and disease.

What influence has the cord upon the functions controlled by the sympathetic system?

Very great. The secretion of many of the body fluids and the control of the organs is dependent for regulation upon the connection of the sympathetic nerves with the spinal cord.

THE MEDULLA OBLONGATA.

Describe, roughly, the medulla oblongata.

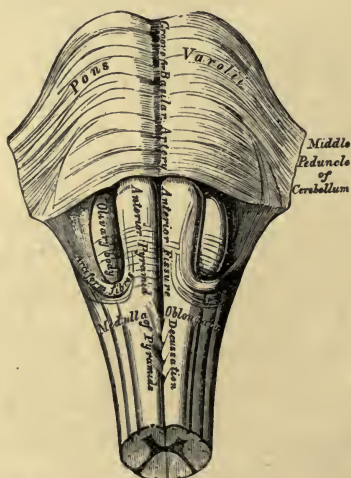
It is a column of white and gray nerve-substance, and is an en-

larged portion of the spinal cord, connecting the brain with the cord below. The white substance is composed of the medullary fibres connecting brain and cord, and the gray matter is arranged variously between the bands of white fibres. It has an anterior and a posterior fissure, corresponding to those of the lower portion of the cord, and the central canal of the cord here opens into the fourth ventricle.

How do the columns of the cord arrange themselves in the medulla?

The medulla continues in a general way the arrangement of the fibres in tracts of the cord below, but as the diameter is greater the general shape is pyriform and the shape of the columns nearly pyramidal (Fig. 31). The anterior columns of the cord become the

FIG. 31.



Medulla Oblongata and Pons Varolii, anterior surface.

anterior pyramids of the medulla; the posterior columns, the restiform bodies, and the lateral columns correspond to the lateral tract of the medulla with the olivary bodies. The fibres, however, do not follow this arrangement so closely, but the columns of the cord distribute themselves variously in the medulla.

How are the anterior pyramids made up?

The anterior columns of the cord send their fibres (the direct pyramidal tract) up into the anterior pyramids, so that they are continuous tracts. Other fibres from the lateral columns join the fibres of the anterior pyramids, and here cross in bundles to the opposite side. These fibres may be seen crossing the anterior fissure between the pyramids by gently separating the anterior pyramids. This is known as the *decussation of the pyramids*. The fibres which cross in this way belong in the cord to the portion of the lateral column known as the crossed or lateral pyramidal tract.

How are the fibres of the anterior pyramids distributed to the brain?

Most of the fibres pass on through the pons Varolii to be distributed in the cortex of the brain. Some of the fibres help to make up the *fillet*, and pass to the optic thalamus, while others pass to the cerebellum. Fig. 32 shows these relations very satisfactorily.

FIG. 32.



Diagram of the Course of the Fibres through the Medulla to the Brain.

How does the lateral column of the cord communicate with the brain through the medulla?

The lateral column of the cord is broken into three tracts in the medulla: one, we have just seen, joins the anterior pyramid of the opposite side by the decussation; a second joins the restiform body

on its way to distribution in the cerebellum; while the third set of fibres goes to the fasciculus teres, and reaches the ganglia at the base of the brain. (See Fig. 32.)

What is the mode of connection of the posterior column of the cord?

Its fibres continue on as the posterior pyramid of the medulla and restiform body. The former probably communicates with the basal ganglia, though it has not been traced as far, and the latter (restiform body) for the most part reaches the cerebellum.*

What are the olivary bodies?

Each is a mass of white nerve-substance containing a central gray nucleus. There are communications between it and some of the tracts from the cord, especially from those tracts of the anterior and lateral columns which go to the ganglia at the base of the brain.

How is the gray substance arranged in the medulla oblongata?

As the fibres which form the crossed pyramidal tract pass from the lateral tract to decussate into the anterior pyramid of the opposite side, they push the anterior cornu of the gray matter backward; and this is still further accomplished by the olivary body, until the gray matter is spread out upon the posterior surface of the medulla at its upper part. Here the central canal of the cord has widened out to form the fourth ventricle, and the gray substance is aggregated to form the floor of the ventricle. There are some other collections of gray matter—for example, in the olivary bodies—but this is the principal accumulation.

What especial importance has this collection of gray substance in the floor of the fourth ventricle?

In this nucleus are the origins of some of the cranial nerves: the spinal accessory, hypoglossal, pneumogastric, and glosso-pharyngeal nerves, and a root of the auditory of the facial, and of the trigeminus nerves, arise in this important collection of gray matter.

* In speaking of these fibres it has been convenient to say that they "pass" in certain directions or "are distributed" in some situation. It must not be forgotten that they are afferent and efferent medullated nerve-fibres, and that such terms must be considered as somewhat figurative. In reality, it would not seem proper to speak of an efferent fibre as being "distributed" at its origin, but convenience and usage permit the use of these and similar expressions.

Of the smaller collections of gray substance, probably none has the peculiar interest which the floor of the fourth ventricle possesses for this reason.

What are the functions of the medulla oblongata?

The medulla has practically the same functions as the cord, conduction and reflexion; but in both these qualities it excels the cord, for in the conduction of impulses it has to transmit all that pass between the brain and spinal system, and in the reflex actions which it originates it is much more elaborate than the cord. The automatic reflex actions of the medulla involve the rhythm of the vital organs, respiration and heart-action.

How may the functions of the medulla be demonstrated in the frog?

If the spinal cord be removed up to the medulla, the respirations continue, and in the same way they do not cease if the brain be removed without disturbing this organ, or, if both cord and brain be removed without disturbing the medulla, the movements of breathing will continue. If the medulla is injured at the origin of the pneumogastric nerve, however, the movements of respiration cease and the animal dies. The same occurs when a similar injury occurs in the higher animals and in man. Death occurs instantaneously in this way when the medulla is broken near the axis in executions by hanging—"the neck is broken"—or an animal is killed by "pithing" in laboratory experiments.

What are the special centres in the medulla?

There are a considerable number of centres in the medulla which control many important and complicated co-ordinated muscular actions. These are centres of reflex action for the most part; that is, are called upon to act in response to stimuli derived from an afferent impulse or to a voluntary effort.

What is meant by automatism of the medulla?

The impulses which are sent out to muscles without apparent afferent stimuli, and without an effort of the will, are called automatic. Such rhythmic impulses as those which maintain the respiratory function belong to this class. It is not to be doubted that such actions are reflex and in response to stimuli. In the case of the lungs, for example, the presence of deoxygenated blood may serve to excite an afferent impulse. Nevertheless, some authors distin-

guish between automatism and reflex action. This automatic action cannot be considered as at all the same as an action of the brain proper, like volition, but rather as a high grade of reflex action.

What other functions are attributed to the medullary centres?

The control or inhibition of action through the nerves which are distributed from this region and through the communications with other centres in the cord. Further than this, there are supposed to lie in the medulla centres which maintain the nutrition and tone of the muscles. These are known as *control* and *tonic* centres.

Name some of the reflex functions depending upon the centres in the medulla.

(1) The portion of digestion which is performed in the mouth is dependent upon medullary reflexes—mastication, deglutition, and the *secretion of saliva*, and, probably, of the pancreatic and other digestive juices. In this connection the so-called *vomiting centre* may be noted.

(2) The *respiratory* functions are so-called automatic functions of the medulla, and are capable of being sustained by the nerve-force derived from the medulla alone. The centres for *coughing* and *sneezing* are also here. The pneumogastric and phrenic nerves convey the afferent and efferent stimuli, though there may be communications with other nerves whereby sensory stimuli are applied.

(3) Regulation of the *heart's action* is found here, both *inhibitory* and *accelerator* centres communicating through the vagus.

(4) *Vaso-motor*,—regulation of the unstripped muscular fibre of the arteries is also accomplished by the medulla. A peculiar vaso-motor disturbance is brought about by injury of one centre of the medulla—namely, the interference with the glycogen-function of the liver and the appearance of sugar in the urine—the *diabetic* centre.

(5) Various centres which have to do with the regulation of the *body-temperature*. The vaso-motor centres we have already mentioned. There are also found special *sweat*-centres; and, furthermore, a control of the special sweat-centres found in the cord is here maintained. Upon plausible theoretical grounds there is also assumed to be a *heat-inhibitory centre*, by which the heat-production is controlled without reference to vaso-motor conditions.

What other important functions are supposed to belong to the gray matter of the medulla ?

The origin of the roots of certain of the cranial nerves here has caused the special senses of *hearing* and of *taste* to be referred to this region ; and the connection with the sympathetic system through the cord has caused the centre for the *dilatation of the pupil* to be located in the medulla. *Phonation* is also dependent upon the action of nerves arising in this focus of gray matter, and no voluntary or reflex sound can be produced by an animal in which the speech-centre in the medulla is destroyed. The origin here of the hypoglossal and pneumogastric nerves, involving as they do the movements of the tongue and glottis, controls both the acts of phonation and articulation.

What is glosso-labio-laryngeal paralysis ?

It is a progressive degeneration of the gray matter of the medulla, and it shows itself first in a paralysis of the tongue, which renders articulation of certain sounds indistinct : as the degeneration progresses in the medulla the articulation becomes more and more impossible and deglutition is affected. The disease continues to affect more and more of the functions dependent upon the medulla, until death ensues as a result of involvement of the cardiac and respiratory centres or of inability to take food. It is sometimes called bulbar paralysis.

With such varied and important powers, can the medulla be classed as an organ of the mind ?

It cannot, for the reason that it has no voluntary control of any of its powers. They are all reflex, or respond to volition originating elsewhere in the brain. Though the regulation of the action of the heart and of the lungs is dependent upon the medulla, and many other functions of absolute need may be given to it, yet its power is not of a character to permit it to be called an organ of the mind.

THE PONS VAROLII AND CRURA CEREBRI.

What is the pons Varolii ?

It is a collection of nervous tissue lying immediately above the medulla. It consists of white fibres, with areas of gray matter filling in the intervals between the fasciculi of white fibres. The white fibres connect the brain with the medulla, and join the

various parts of the brain one to another. What is the function of the gray matter is little known, but it is directly continuous with that of the medulla, and probably, like it, active as a centre of nervous force. The median line of the pons is marked by the decussation of many nerve-fibres, and it is probable that the fibres of the facial nerve arising in the floor of the fourth ventricle decussate here.

What peculiar paralyses are caused by lesions of the pons?

The so-called *crossed paralysis* may follow lesions in the lower portion of the pons; that is, paralysis of sensation and motion, more or less complete, of the opposite side of the body, with paralysis of the facial muscles of the same side as the lesion.

Describe the crura cerebri.

The crura are formed largely of fibres passing from the medulla, through the pons Varolii, to the hemispheres of the cerebrum. They divide so as to form two sets of fibres: the more superficial (crusta) are mostly motor or efferent fibres which are continuous with the pyramidal tracts in the cord; while the deeper (tegmentum) layer of fibres are afferent or sensory, and are derived largely from the lateral and posterior tracts of the cord. Lying between these bands of fibres is a mass of gray substance (locus niger) whose function as a nerve-centre is not understood, though it has to do with co-ordination of the muscles, and especially with regulation of the muscles controlled by the motor oculi nerve.

What paralyses follow lesions in the crura cerebri?

Paralysis of the opposite side of the body, both of sensation and motion, and of a degree of intensity depending upon the size of the lesion, and, besides this, paralysis of the motor oculi nerve of the same side as the lesion. There is a derangement of the ordination of motions which follows lesions of this region beyond that which belongs to the motor paralysis; this is often shown in rotary movements when the subject attempts to walk. It is inferred that there are co-ordinating influences derived from the crura.

What is the function of the corpora quadrigemina?

The corpora quadrigemina are the homologues of the optic lobes in some of the lower animals, and may be regarded as important centres for the visual and motor functions of the eyes. Not only does blindness follow lesions of the corpora quadrigemina, but there is often atrophy of them when the eyes are destroyed.

Their action is crossed; that is, lesions of the left side produce right blindness. From these bodies also is derived the power of co-ordination of the movements of the eyes and the control of the reflex of the pupil. These centres are closely related, and the disturbance of the one by a lesion in this part usually involves the other.

THE CEREBRUM.

Describe briefly the cerebrum.

It is composed of two parts, or *hemispheres*, connected by a commissure of white fibres, the *corpus callosum*. The two hemispheres are separated by a deep fissure extending fore and aft, and in the interior of each is found a cavity known as the *lateral ventricle*. The hemispheres are connected directly with the spinal system by the *crura cerebri* and *medulla*, and with each other by the *corpus callosum*. They are composed of white and gray nerve-substance, and the latter is arranged largely at the periphery of the hemispheres; the former being made up of communicating nerve-fibres which connect the various portions of the hemispheres, and the hemispheres with other parts of the cerebro-spinal system, thus allowing a free control of the impulses arising from one cell or set of cells by other cells in the gray matter.

How is the surface of the cerebrum marked?

It is divided into regions by *fissures*, which separate one part from another. These fissures are always present, and upon them depends the determination of the division of the cerebrum into *lobes*. The fissures which are of most use in locating the lobes of cerebral matter are the fissure of Rolando, the fissure of Sylvius, and the parieto-occipital fissure.

What are the convolutions of the cerebrum?

The surface of the brain is further cut up by a number of other clefts, known as *sulci*; and these separate the surface into a number of distinct masses or convolutions. The depth of the sulci and their number determine the quality of the brain in respect to its degree of development; thus, the convolutions in man are much deeper and more numerous than in the lower animals. The sulci are not invariable in position or number in different brains.

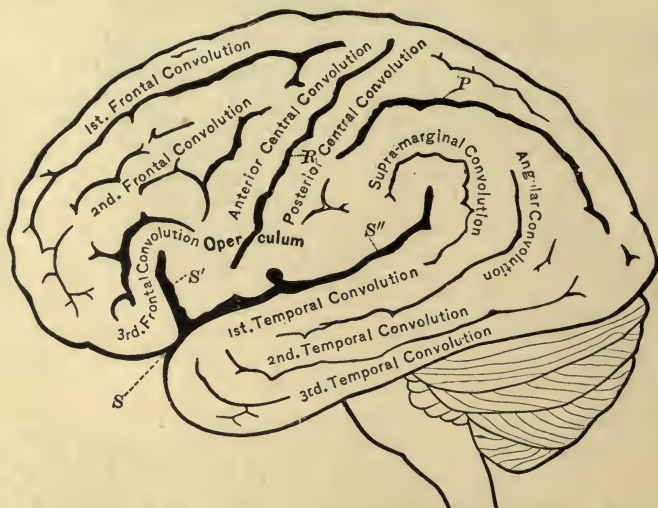
Into what regions is the cerebrum divided by the fissures?

(1) *Frontal Lobe*.—This lobe is bounded by the fissure of Rolando,

and contains several convolutions which include the forward portion of the brain.

(2) The *Parietal Lobe* lies behind the fissure of Rolando, and extends posteriorly to the occipito-parietal fissure. The convolutions are well marked, and are separated by a well-marked sulcus

FIG. 33.



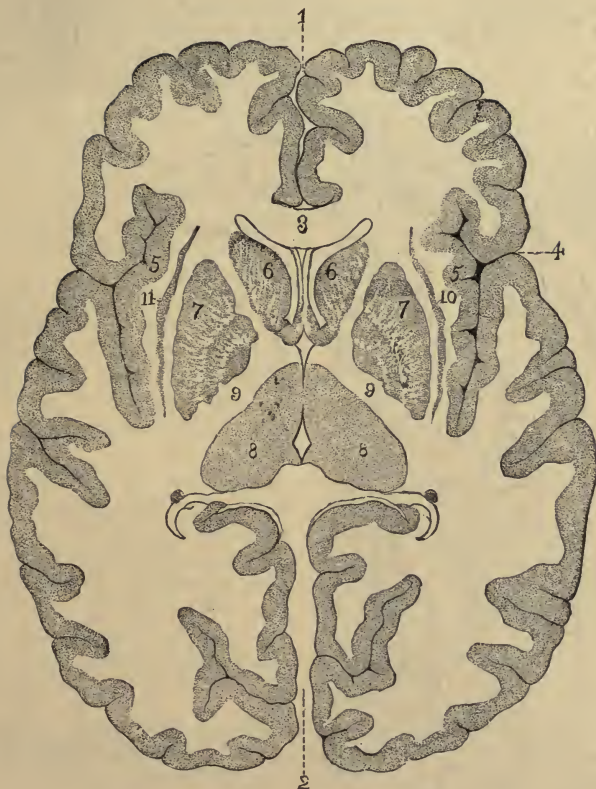
Plan of the Human Brain in Profile, showing its fissures and convolutions: *S*, fissure of Sylvius; *S'*, anterior branch; *S''*, posterior branch; *R*, fissure of Rolando; *P*, parieto-occipital fissure.

(sometimes known as the parietal fissure), and the posterior branch of the fissure of Sylvius is often enfolded by the inferior parietal convolution. (In Fig. 33 this convolution is marked "Supramarginal convolution.")

(3) The *Temporo-sphenoidal Lobe* is below the Sylvian fissure and in front of the parieto-occipital. Its convolutions are well marked.

(4) The *Occipital Lobe* is found at the posterior end of the cerebral hemisphere, and its convolutions are continuous with those of the parietal and temporo-sphenoidal lobes, except within the longitudinal fissure, where it is cut off from them by the parieto-occipital fissure.

FIG. 34.



Horizontal Section of the Hemispheres at the Level of the Cerebral Ganglia: 1, great longitudinal fissure between frontal lobes; 2, great longitudinal fissure between occipital lobes; 3, anterior part of corpus callosum; 4, fissure of Sylvius; 5, convolutions of the insula; 6, caudate nucleus of corpus striatum; 7, lenticular nucleus of corpus striatum; 8, optic thalamus; 9, internal capsule; 10, external capsule; 11, claustrum.

(5) The *Central Lobe*, or *Island of Reil*, is within the fissure of Sylvius and covered by the convolutions of the frontal and parietal lobes. (See 5 in Fig. 34.)

Besides these well-defined lobes, the portion of the cerebral sur-

FIG. 35.



Gray Matter of the Cerebral Cortex (Meynert).

face which is within the longitudinal fissure is marked by sulci and convolutions. The convolutions of the frontal, parietal, and occipital lobes are found here, and the *marginal* (or calloso-marginal) convolution, lying above the corpus callosum, is the principal landmark.

How is the gray matter of the cerebrum arranged?

The increase in the area of the surface of the hemispheres by the infolding of the sulci adds very greatly to the amount of gray substance in the brain; for the entire surface is composed of gray substance, and this follows the sulci and fissures (Fig. 34) in all their folds, and is not cut into by them. Besides the gray matter in the convolutions there are certain other gray masses in the substance of the white matter: the optic thalami, the corpora striata, and the claustrum (Fig. 34) are the chief of these gray masses.

What is the minute structure of the gray matter of the cortex?

The gray matter of the cortex is made up of ganglion-cells of various shapes and sizes lying in a loose connective-tissue stroma. The connective tissue is more abundant at the surface. The cells are the source of numerous nerve-fibres which pass out into the white matter (Fig. 35). There are counted five layers of these ganglionic tissues, and, while

these zones merge into one another, they are tolerably distinct. In the middle (and widest) layer large multipolar cells are very numerous, and the fibres may be seen to pass through the deeper layers in bundles into the white matter.

What chemical peculiarities does nervous tissue present?

It contains some peculiar bodies allied to the fats, but containing nitrogen: of these *cerebrin* and *lecethin* are the more prominent. Aside from this, the constituents are proteid and fatty substances, with salts, chiefly potassium and magnesium phosphates, and water.

What is the weight of the adult brain?

About 3 pounds. In size it exceeds the brains of all the lower animals except the elephant and whale. Its weight is about one-fortieth of the total body-weight, and this ratio is greater than in the lower animals, with a few exceptions among the smaller birds and monkeys. In women the weight is about one-tenth less than in men.

Is the size of the brain a criterion of intellect?

In some degree it is, but this is not absolute. The depth of the sulci, and consequent size and complexity of the convolutions, are a more efficient measure of the brain-power. In the largest of the apes the brain of an adult animal is about the same in weight as that of a human infant at birth. Idiots, as a rule, have brains much smaller than the normal, and in them the convolutions are apt to be ill-marked and uncomplicated, as is the case in the lower animals.

What is known of the course of the fibres in the white substance of the hemispheres?

The course of these fibres may be classified in three groups: 1, commissural fibres; 2, fibres of association; and 3, medullary fibres.

(1) The *Commissural Fibres* are those which connect one hemisphere with the other, and it may be said that these fibres connect each set of convolutions with the corresponding set of the opposite side. The convolutions of the portion of the brain lying above the fissure of Sylvius communicate by the corpus callosum, while those at the base of the brain are joined by fibres passing through the anterior commissure.

(2) *Fibres of Association* are those fibres which connect the convolutions of one hemisphere. These fibres pass in bundles just beneath the cortical gray matter of the convolutions, and it is thought that most of the important convolutions of each hemisphere intercommunicate in this way.

(3) The *Medullary Fibres* are those which connect the cerebrum and medulla, and are regarded as indirect and direct, according as they do or do not pass to the gray ganglia at the base of the brain. In considering the course of the fibres from the medulla through the crura cerebri it was noted that the motor and sensory fibres were to some extent separated. The fibres pass from the crura to the internal capsule, and here the course of the fibres is twofold: the "direct fibres" pass to the cerebral convolutions through the corona radiata, while the "indirect fibres" pass to the corpora striata and optic thalami, and communicate with ganglion-cells there.

What is the function of the corpora striata and the optic thalami?

These "basal ganglia," with the other collections of gray substance outside the convolutions, seem to have a controlling influence upon the spinal system. The crura throw their fibres largely to these ganglia, the motor pyramidal tracts to the corpora striata, and the sensory fibres from the lateral and posterior tracts to the optic thalami. It is through these ganglia that all voluntary impulses, except those by the direct medullary fibres, must pass. These basal ganglia communicate through the corona radiata with the convolutions of the cortex, and it is probable that we may regard this part as acting as a middleman to elaborate and co-ordinate the voluntary impulses of the cortex and to act in the matters not requiring the intervention of the higher endowments of the mind. This status of these ganglia is quite theoretical, but the function may be considered as a sort having the properties of both the automatism of the gray matter of the medulla and cord and the voluntary function of convolutions. In this consideration, however, we must not undervalue the communication with the cortex which these basic ganglia possess.

Do lesions in these basic ganglia cause peripheral symptoms?

No. So far as has been observed, the corpora striata may be involved by considerable lesions without causing persistent motor or sensory disturbances, and the same may be said of the optic

thalami, but if the lesion encroaches upon the white matter of the internal capsule or *crura cerebri*, the effect is to cause more or less paralysis, depending upon the severity of the lesion and its position.

What are the functions of the cerebrum ?

The motor and sensory functions which have been seen to belong to other nuclei of gray matter are centred here, but infinitely broadened, for the cells in the convolutions of the cerebrum can originate the efferent and perceive the afferent nerve-impulses. In fact, it is in this portion of the brain that the intelligence is centred: it is the organ of the mind. Memory, reason, emotions, and all the other attributes of the mind are dependent upon its functional power.

What is the effect upon animals of the removal of the hemispheres ?

In some of the lower animals the cerebrum may be entirely removed without killing them. When this is done, for example, in the case of a pigeon, the bird remains quiet in one position, and is not disturbed by noises, or if thrown from its perch it flies and alights in a nearly normal manner. If a foot be pinched, it withdraws it and perhaps changes its position. The bird is capable of reflex actions of various complicated kinds, but there is no spontaneous exercise of volition: all its movements are excited by the nerve-stimuli of the moment. There is no perception of stimuli; the intelligence is gone.

What is unilateral action of the brain ?

There are instances in which the injury or disease of one-half of the brain has left the intellectual faculties not gravely impaired. From a consideration of such cases it has been held that the action of one of the hemispheres was sufficient for the purposes of the mind. There is, however, an absolute dependence for motor and sensory functions upon the integrity of both sides, for the one side cannot act for the other in these functions. As a rule, it is safe to assume that the two hemispheres act in unison.

Are the functions of the brain localized ?

While the brain is regarded as an organ of the mind, it is probable that the various functions may be regarded as belonging to definite portions of the convolutions which are appropriated for that

purpose. The functions of the convolutions have not been assigned, except for a very small portion of the brain-surface and for some of the simpler actions. For the most part, our knowledge of the localization of brain-functions is confined to "motor areas," in which it has been determined that stimulation of a certain group of cells will cause a definite action. Besides this, certain other centres are located, as of sight and speech.

How are the motor areas determined?

When the surface of the brain is exposed in animals or in man, the stimulation of certain areas of the cortex by a mild electrical current will give rise to motion in the peripheral muscles; and it is found that the stimulation of the same region in the same or other animals will cause the same results. These centres of motor impulses are situated almost entirely upon the convolutions about the fissure of Rolando (Fig. 36).

What is known regarding the localization of sensory areas?

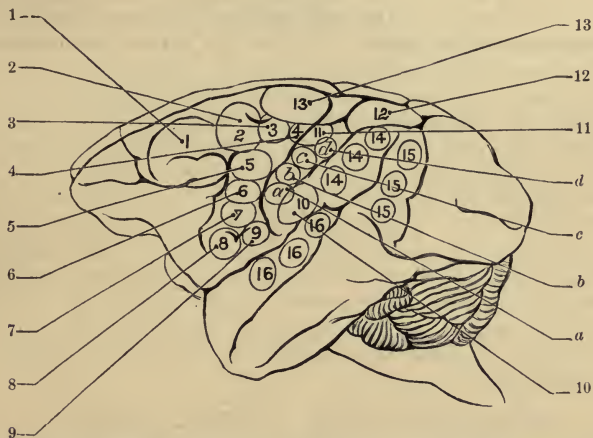
This has not been, by any means, so definitely fixed as for motor centres; but the centres for sensation may be said to exist, and probably in the convolutions of the posterior portion of the cerebrum. The centre for *vision* in the convolutions about the posterior branch of the fissure of Sylvius is generally accepted (14, 15, in Fig. 36). The centre for *hearing* is tolerably defined in the temporo-sphenoidal lobe along the posterior branch of this fissure (16, Fig. 36). The *speech*-centre is also located with seeming accuracy along the anterior branch of the fissure of Sylvius and in the island of Reil. This centre seems to be much more developed upon the left side of the brain. In Fig. 36 this centre may be indicated roughly by reference to the tongue-centres (8 and 9).

Do the evidences of pathology agree with these experiments?

Injuries and diseases involving the motor areas are followed by paralysis so well defined that it is frequently possible to locate the seat of the lesion from its result upon the muscular system. Tumors, abscesses, and depressed bone, for example, are capable of accurate localization in this way. The more indefinite sensory paralyses do not so accurately point out their origin. On the whole, the evidence of pathology bears out in full the experimental results. The crossed action of all the nervous structures is especially to be noted. In the case of a right paralysis in

which the speech is affected, as compared with a left hemiplegia and speech unaffected, this crossed action is impressed when we

FIG. 36.



Brain of Monkey, showing the position of the motor and sensory centres as ascertained by Ferrier. The actions all occur on the side of the body opposite to the part of the brain irritated: 1, the eyes open widely, the pupils dilate, and head and eyes turn toward opposite side; 2, extension forward of the opposite arm and hand, as if to reach something in front; 3, movements of tail (and trunk); 4, retraction with adduction of opposite arm; 5, supination and flexion of the forearm, by which the arm is raised toward the mouth; 6, action of zygomatics, by which the angle of mouth is retracted and elevated; 7, elevation of ala of nose and upper lip; 8, opening of mouth with protrusion of tongue; 9, retraction of tongue; 10, retraction of opposite angle of mouth; *a*, *b*, *c*, *d*, prehensile movements; 11, retraction and adduction of opposite arm; 12, advance of the opposite hind limb; 13, complex movements of thigh, leg, and foot; 14, 15, vision (sensory); 16, hearing (sensory).

remember the localization of the centre for speech in the left hemisphere near the motor area.

Mention some of the common terms used in defining paralysis.

Anæsthesia = loss of sensation.

Hemianæsthesia = loss of sensation in one lateral half of the body.

Hemiplegia = loss of muscular power in one lateral half of the body.

Paraplegia = symmetrical loss of muscular power in the lower portion of the body and extremities.

Aphasia = loss of power to talk—amnesic when words are forgotten; ataxic when the power to articulate is lost, though the words are known.

THE CEREBELLUM.

Describe the cerebellum.

It is a mass of nerve-substance situated posteriorly at the base of the skull. It consists of a median lobe and two lateral hemispheres, and is connected with the rest of the cerebro-spinal system by numerous white fibres collected in bundles known as peduncles. Of these, the larger peduncles pass to and largely make up the pons Varolii (middle peduncles), thus connecting the lateral hemispheres of the cerebellum. The superior peduncles (or processus e cerebello ad testes) pass beneath the corpora quadrigemina, and the fibres pass into the white matter of the cerebrum, decussating as they meet beneath the corpora quadrigemina. The inferior peduncles pass to the medulla, where they form the restiform bodies. Thus it is seen that the entire cerebro-spinal system communicates very freely with the cerebellum.

How is the gray matter of the cerebellum arranged?

The arrangement in convolutions is not the same as in the cerebrum, but there are numerous transverse sulci which divide and subdivide, the gray matter being disposed about them in a thin layer. This causes a section of the organ to have a peculiar tree-like appearance, which originates the name, “arbor vitæ,” given to the cortical matter of the cerebellum. Besides this, there is a central collection of gray substance—the corpus dentatum.

What peculiarities does the gray matter of the cerebellar cortex possess?

Under the microscope it is found to consist of three layers (Fig. 37). The outer is a layer of delicate connective tissue which supports fine nerve-fibres and small spindle-shaped, branching nerve-cells. The middle layer is characterized by irregularly disposed large ganglion-cells, and the branching processes from these ramify in the superficial layer. These cells are known as *Purkinje's cells*. The inner layer is made up of a mass of small spheroidal cells, and gradually merges into the white substance.

What is the function of the cerebellum?

The cerebellum seems to exert no influence upon the sensory

FIG. 37.



Vertical Section through the Gray Matter of the Human Cerebellum (magnified about 100 diameters: Klein and Noble Smith): *a*, the external gray or cellular layer; *b*, corpuscles of Purkinje; *c*, internal rust-colored granular layer; *d*, white substance. Two branched capillaries are seen at the upper part passing into the gray matter from the pia mater.

nerves, for sensibility is not affected by its injury or disease. The motor system is, however, entirely disorganized by lesions of the organ. *Co-ordination* of the voluntary muscles is accomplished by this portion of the brain, and it is originated in the gray matter of the part. It has no effect upon the senses or upon the intellect, so far as is known.

What is the effect of removing the cerebellum in animals?

When small portions are removed the animals become feeble and uncertain in their movements, but are able to move for ordinary purposes. As the amount removed increases the want of co-ordination of the voluntary muscles increases. With the entire cerebellum gone the condition is absolute—animals cannot stand or walk or bring any of the muscles into orderly action. If the animal is laid upon the back, it cannot recover itself, but struggles vaguely in the attempt. The senses are apparently normal and the will-power is present: if a blow is threatened, an attempt is made to avoid it. When the lesion is confined to one hemisphere, the lack of co-ordination is noticed in the opposite half of the body. Under these circumstances the animals are apt to fall to the opposite side and roll over and over rapidly. Such movements are known as *forced movements*. This condition may persist for several days. Pigeons from which the cerebellum is removed may live for a considerable time, sometimes for several months, after the operation. In some cases there is a return of power to co-ordinate, after partial removal, at the end of some days.

THE CRANIAL NERVES.

What are the cranial nerves?

They are a set of twelve pairs of nerves which arise from the brain. They are varied in their functions, but all arise from ganglia of gray matter in the brain and medulla. The floor of the fourth ventricle is particularly rich in nuclei in which these cranial nerves originate.

How may the cranial nerves be classified?

1. In the order of their emergence, by numbers: (I) Olfactory; (II) Optic; (III) Motor oculi; (IV) Patheticus; (V) Trigeminus; (VI) Abducens; (VII) Facial; (VIII) Auditory; (IX) Glossopharyngeal; (X) Pneumogastric; (XI) Spinal accessory; (XII)

Hypoglossal.* In the relation of their functions they may be arranged as nerves of special sense, nerves of common sensation, motor nerves, and mixed nerves (*i. e.* both sensory and motor).

Nerves of special sense,	{ (I) olfactory, (II) optic, (VIII) auditory†, and parts of (V) trigeminus and (IX) glosso-pharyngeal.
Nerves of common sensation,	{ The greater portion of the (V) trigeminus.
Motor nerves,	{ (III) motor oculi, (IV) patheticus, (V) lesser division of the trigeminus, (VI) abducens, (VII) facial, and (XII) hypoglossal, (XI) spinal accessory (?).
Mixed nerves,	{ (IX) glosso-pharyngeal and (X) pneumogastric.

What is the distribution of the motor oculi or third nerve?

It arises from a nucleus of gray matter just in front of the medulla, beneath the *iter e tertio ad quantum ventriculū*, passing out through the *crus cerebri*, and emerging from the skull in the orbit. It gives off some fibres to the lenticular ganglion. It is distributed to all the muscles of the eyeball, with the exception of the superior oblique and the external rectus muscles. It also supplies the levator palpebræ superioris muscle, and by its connection with the lenticular ganglion controls the ciliary and pupillary muscles.

What is the function of the third nerve?

It is a purely motor nerve. Its function is best described, perhaps, by showing the paralyses which follow its division: by paralysis of the elevator of the upper lid we have *ptosis*; by the paralysis of the muscles of the eyeball we have inability to move the organ up or down or inward; by the unopposed action of the external rectus the eyeball becomes turned outward (*external strabismus*); by the action upon the muscle of the iris the pupil

* A convenient old medical-school mnemonic is useful in remembering the names and order of these nerves—viz. On Old Moriah's Pointed Top A French And German Picked Some Hops, the initial letter of each word giving the key. It is given with an apology to many generations.

† Of the nerves of special sense, (I) olfactory, (II) optic, and (VIII) auditory will be explained later, and may be omitted from further consideration for the present.

remains dilated and does not respond to light; and by the paralysis of the ciliary muscle the accommodation of the lens for near vision is prevented. The control of the pupil is not a voluntary one; but the effect of a strong voluntary effort, exerted through the third nerve, shows itself in contraction of the pupil, as when the eyeball is turned strongly inward and upward.

Describe and give the function of the patheticus or fourth cranial nerve.

It arises close by the third nerve beneath the aqueduct of Sylvius, and emerges, after decussation, from the valve of Vieussens. Thence, passing around the crus cerebri, it runs parallel with the motor oculi (third) nerve to the orbit, where it is supplied to the superior oblique muscle. Its paralysis prevents the muscle from maintaining the horizontal plane of the eyeball. If this paralysis occurs, there is double vision, and the image seen by the affected eye appears oblique and inferior to the image of the other eye. This may be corrected by inclining the head to the opposite side. This nerve is also known as the *trochlearis* or *trochlear nerve*.

What is the course and function of the sixth or abducens nerve?

It arises from a nucleus of gray matter in the floor of the fourth ventricle, and its nucleus is connected with those of the third, fourth, and seventh nerves. It emerges without decussation at the posterior border of the pons Varolii, and passes forward to the orbit with the third and fourth nerves. In its course it has many communications with the sympathetic nerves, but their significance is unknown. It is supplied to the external rectus muscle of the eye, and its stimulation causes external squint, and paralysis causes internal.

What is the origin of the trigeminus or fifth nerve?

This nerve resembles the spinal nerves in having a motor and a sensory root, the latter possessing a ganglion (Gasserian). The origin of the nerve seems to be in centres, separate for motor and sensory, in the floor of the fourth ventricle. There are fibres which join the trunk of the nerve which are derived from the spinal cord and from the cerebellum. It emerges from the pons Varolii as two distinct nerve-roots. The larger of the two, the sensory, soon enters the Gasserian ganglion, the motor root passing beneath without communication. The nerve then breaks up into three branches: of these the first and second are formed entirely from the sensory

root, while the third carries all the motor fibres, and with them some of the sensory, so that the third branch of the nerve is partly sen-

FIG. 38.

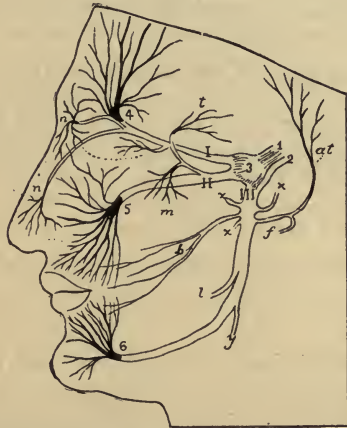


Diagram of the Fifth Nerve and its Distribution: 1, sensitive root; 2, motor root; 3, Gasserian ganglion; I, ophthalmic division; II, superior maxillary division; III, inferior maxillary division; 4, supraorbital nerve, distributed to the skin of the forehead, inner angle of the eye, and root of the nose; 5, infraorbital nerve, to the skin of the lower eyelid, side of the nose, and skin and mucous membrane of the upper lip; 6, mental nerve, to the integument of the chin and edge of the lower jaw, and skin and mucous membrane of the lower lip; *n, n*, external terminations of the nasal branch of the ophthalmic division, to the mucous membrane of the inner part of the eye and the nasal passages, and to the base, tip, and wing of the nose; *t*, temporal branch of the superior maxillary division, to the skin of the temporal region; *m*, malar branch of the superior maxillary division, to the skin of the cheek and neighboring parts; *b*, buccal branch of the inferior maxillary division, passing along the surface of the buccinator muscle, and distributed to the mucous membrane of the cheek and to the mucous membrane and skin of the lips; *l*, lingual nerve, to the mucous membrane of the anterior two-thirds of the tongue; *at*, auriculo-temporal branch of the inferior maxillary division, to the skin of the anterior part of the external ear and adjacent temporal region; *x, x, x*, muscular branches, to the temporal, masseter, and internal and external pterygoid muscles; *y*, muscular branch, to the mylo-hyoid and anterior belly of the digastric; *f*, sensitive branch of communication to the facial nerve.

sory and partly motor. There is a partial decussation of the fibres in the medulla, but many pass direct to the same side.

What muscles are supplied by the motor root?

The *muscles of mastication*. The temporal, masseter, and both pterygoid muscles, as well as the anterior belly of the digastric.

muscle and the mylo-hyoid, receive their innervation from the motor root of the fifth nerve. Besides this, the tensor palati and tensor tympani muscles are supplied by this nerve through its communication with the otic ganglion of the sympathetic system. A branch to the buccinator muscle is probably not motor, but sensory. Lesions of the nerves paralyze these muscles.

What is the distribution of the sensory root?

The sensory fibres of the fifth nerve are distributed in all three branches, and supply sensation to the skin of the face and anterior portion of the head, emerging from the bony canals upon the face at the supraorbital, infraorbital, and mental foramina; it is also supplied to the mucous membrane of the mouth and tongue (by the lingual branch) and to the muscles of the part.

What results follow division of the sensory root of the fifth nerve?

There is complete anæsthesia of the skin and mucous membranes of the face.

What is the trophic influence of this nerve-root?

It is of very great value. If it be divided, the complete anæsthesia of the conjunctiva, of the nostrils, and of the lips prevents the reflex self-protection which belongs to the parts, and they become injured very easily. Aside from that, the direct influence upon all the parts is great, so that when it is cut off there is a rapid degeneration resulting, which is specially apparent in the mucous membrane of the nose and in the cornea.

What influence has the sensory branch upon the special senses?

(1) Its division causes total anæsthesia to the skin and mucous membrane; the loss of the sense of *touch* in the part is of great importance, for the tongue and lips are used much for this. (2) Upon the sense of *sight* it has a very controlling influence, for, as we have seen, the trophic influence is essential to the maintenance of the integrity of the eye. (3) Upon the sense of *smell*. Here the influence is the same as with the eyes, trophic. The smell is soon lost on account of degeneration of the mucous membrane after division of the fifth nerve. (4) *Taste*, probably, is not a direct function of the nerve, but if the tactile sensibility is gone and the trophic changes are begun, the sense of taste soon disappears in the anterior portion of the tongue. (5) Upon the *hearing* the effect is more gradual and less distinct. The secre-

tions of the cavity of the tympanum and of the external auditory canal are of great importance in maintaining normal conditions. They are under the trophic influence of the fifth nerve, both through its auriculo-temporal branch and through its communication with the otic ganglion. The tensor tympani muscle is also supplied by the motor root. Thus, the auditory apparatus is considerably under the control of the nerve.

What painful affections belong to this nerve?

Headaches of the scalp and deeper tissues, and more especially the frontal sinuses, are common. Toothache and facial neuralgia

FIG. 39.

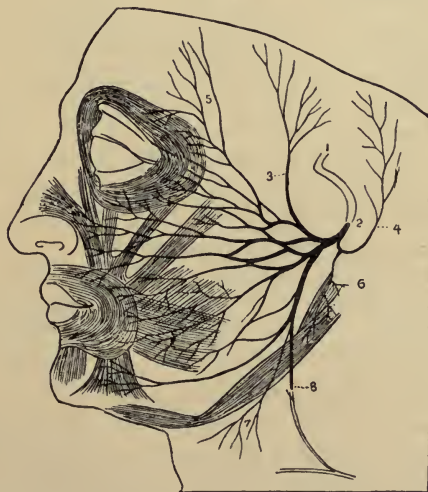


Diagram of the Facial Nerve and its Distribution: 1, Facial nerve at its entrance into the internal auditory meatus; 2, its exit at the stylo-mastoid foramen; 3, 4, temporal and posterior auricular branches, distributed to the muscles of the external ear and to the occipitalis; 5, branches to the frontalis muscle; 6, branches to the stylo-hyoid and digastric muscles; 7, branches to the upper part of the platysma myoides; 8, branch of communication with the superficial cervical nerve of the cervical plexus.

are due to irritation or disease of parts of the nerves. *Tic douloureux* is a persistent neuralgia of some or all of the branches of the nerve.

What is the origin of the facial or seventh nerve?

It arises in the floor of the fourth ventricle, and its fibres emerge at the edge of the pons Varolii in company with the (eighth) auditory nerve (sometimes known as the portio mollis; the facial being then called the portio dura of the seventh pair, when the classification of the cranial nerves is made into nine pairs). It passes into the internal auditory canal, and escapes from the skull by way of the aqueduct of Fallopius and the stylo-mastoid foramen.

How is the facial nerve distributed?

It is almost wholly a motor nerve, and is distributed to all of the muscles of the face (Fig. 39) except those mentioned as controlled by the motor branch of the trigeminus nerve. The muscles of the eyelids and the muscles of the palate in part are innervated by it, as well as the parotid and *submaxillary glands*, through the chorda tympani. In the neck it supplies the posterior belly of the digastric and the platysma myoides muscles. It also sends branches to the stapedius muscle of the internal ear and to all of the muscles of the external ear. The branches passing to the salivary glands are *secretory* in their function; and this is the only exception to the motor influence of the nerve.

What is the function of the facial nerve?

It is the motor nerve which parallels in its distribution the sensory root of the fifth; it supplies the superficial muscles, as the latter does the skin. It is the nerve of expression, by which the features are made to reflect the emotions.

What is the effect of paralysis of this nerve?

If the nerve be divided or diseased, the face of that side is devoid of motion (Fig. 40), and becomes smooth and expressionless, while the sound side is held in its customary pose. The eyelids cannot close themselves, and the lips do not oppose properly, on account of the defective action of the orbicular muscle. There is difficulty in drinking and in articulation for the same reason.

State what influence is ascribed to the chorda tympani branch.

The chorda tympani is a small filament given off from the facial in the aqueduct of Fallopius, some of whose fibres are distributed to the submaxillary gland. If this nerve be divided, the secretion of saliva from the gland is greatly diminished, while stimulation of the

nerve will excite a copious flow. This is an active secretion, and is not a simple filtration due to vaso-motor changes. A similar influence is noted in the corresponding half of the tongue. There is a similar distribution of fibres from the facial to the parotid gland

FIG. 40.



Facial Paralysis of the Right Side.

through the lesser petrosal nerve, but their action has not been so thoroughly analyzed as in the case of the submaxillary and chorda tympani.

The chorda tympani has still further an effect upon the sense of *taste* in the anterior portion of the tongue. If it be divided, the taste is much blunted on the affected side. It is not known if this be due to the communication of the glosso-pharyngeal or not, but it seems probable that it cannot be ascribed to either the trifacial or facial alone; and it is considered to be a plausible explanation that the chorda tympani does bear some fibres of the glosso-pharyngeal.

Why is not the ocular paralysis of the seventh nerve as serious as that of the fifth?

The eyelids remain open in facial paralysis, and the conjunctiva is subject to injury by drying and by foreign bodies; but the injury is not so great as in paralysis of the fifth nerve, because the seventh has no trophic influence.

What is the origin of the glosso-pharyngeal or ninth nerve?

It arises in the medulla from centres near those for the vagus and spinal accessory nerves. Its fibres pass through the substance of the medulla and emerge in company with those of the vagus and spinal accessory to pass with them from the skull through the jugular foramen. It gives off a small branch which passes to the tympanum and Eustachian tube (Jacobson's nerve) while in the jugular foramen, and presents a small ganglion, the petrosal; and it has communicating branches to the seventh and tenth nerves and to the otic ganglion. It divides as it passes down, one branch passing forward to the tongue, and one going to the pharynx (whence its name).

How is the glosso-pharyngeal distributed?

The portion which passes to the tongue is distributed to the posterior portion of the organ, to the circumvallate papillæ, and the mucous membrane behind them, some fibres going to the lining of the soft palate, pillars of the fauces, and tonsils. The other branch is distributed to the mucous membrane of the pharynx, and by direct branches and communications with other nerves to all the muscles involved in swallowing.

What is the function of the glosso-pharyngeal nerve?

(1) It is the nerve of *taste*; and (2) it is essentially a nerve of deglutition.

Explain the action of the glosso-pharyngeal as a nerve of taste.

It is only in the latter part of the stay of food in the mouth that it reaches the region supplied by this nerve. When the food is to be swallowed, it is pressed by the base of the tongue against the palate arch and pushed into the pharynx. It is then that the sense of taste is exercised here. The reflex stimuli then excited start up the motor chain which pushes the bolus on to the stomach. As already said, there is considerable question as to whether the trigeminal or glosso-pharyngeal is really the conductor of this sense, but it is quite likely that both are essential.

What is the function of the glosso-pharyngeal as a motor nerve?

Whether by reason of its communications with other nerves or not in its distribution, the nerve is a motor nerve as well as sensory. Its distribution is to all the muscles of deglutition, and stimulation causes contraction of the muscles, while division paralyzes them. The very numerous connections of the nerve complicate its anatomical origin very greatly, and interfere with a clear comprehension of the unaided function of the nerve.

Where does the reflex for swallowing originate?

In the medulla oblongata, where the centre of origin of the nerve is situated.

What is the origin of the pneumogastric or tenth nerve?

It arises from the gray matter in the floor of the fourth ventricle, its nucleus being very close to those of the glosso-pharyngeal, spinal accessory, and hypoglossal. Its fibres pass through the substance of the medulla oblongata, and emerge from its lateral surface with the roots of its associate nerves, the glosso-pharyngeal and spinal accessory. It passes from the skull with them by the jugular foramen. It has at this point a ganglionic enlargement. From here it passes down the neck, and is distributed more diffusely than any other cranial nerve.

What synonyms has the tenth nerve?

Pneumogastric, from its distribution and function; vagus or Par Vagum, from its scattered distribution (*vagus*, Latin = wanderer).

What principal distributions has the pneumogastric?

It is supplied to the organs by which air and food enter the body, and besides this has several important connections with the sympathetic system. (1) To the larynx it supplies sensation and motion through the superior and inferior *laryngeal branches*. (2) In the chest it forms the *pulmonary plexuses*, which innervate the bronchi and lungs. (3) Branches to the cardiac plexus supply important stimuli to the heart and great vessels. (4) There are branches to the *pharyngeal* and *oesophageal* plexuses which are both sensory and motor, supplying both the mucous membrane and the muscular structures of the parts. (5) Its terminal branches supply the sensory and motor nerves to the stomach, the left nerve being distributed on its anterior wall, and the right posteriorly. (6) Branches

also pass to the liver and spleen and communicate with the solar plexus.

Mention some of its communications with other nerves.

Soon after leaving its origin in the medulla the vagus enters into so many communications with other nerves, both sensory and motor, that it is difficult to know the real fibres of the original root and to determine what are original and what derived functions. The sympathetic system sends fibres in all the branches of the pneumogastric, and the pneumogastric sends branches to many of the important sympathetic plexuses and ganglia; the pharyngeal, laryngeal, œsophageal, pulmonary, cardiac, and solar plexuses are so made up by branches from both. The spinal accessory nerve is an important contributor, in that it sends a large branch which is incorporated in the vagus. There are also communications to the glosso-pharyngeal and hypoglossal nerves, and it also receives motor fibres from the facial and upper two cervical nerves. The original nerve is probably entirely sensory, and its motor function is derived from these connections with motor nerves.

Where are the motor fibres from the spinal accessory nerve supposed to be distributed?

Principally in the recurrent laryngeal nerve.

What is the function of the vagus in connection with respiration?

The nerve supplies, as has been said, the motor and sensory functions of the larynx, and in this is of value to the respiratory function both in the prevention of foreign substances entering the rima glottidis, and in the opening of that orifice for the entrance of air. Besides this, it supplies sensory fibres to the pulmonary plexus which transmit the reflex stimulus to the medulla, by which the motor apparatus is excited to action.

What is its influence upon the voice?

The muscles of the larynx involved in the production of sound are supplied by this nerve, and, as the approximation of the chordæ vocales is necessary for this, it follows that the voice is dependent upon the fibres of the pneumogastric supplied by the inferior or recurrent laryngeal nerve.

What effect upon respiration follows section of the vagi?

The respiration is slowed immediately to about half its usual

rate, and soon drops to five or six to the minute, and even slower. The respiration is easy—inspiration slow and full, expiration harsh and sudden. Death follows this operation in a short time (one to six days), and the animal during the time is sluggish and apparently suffers from slow carbonic-oxide narcosis. It is inferred from this that the vagus is the nerve which carries to the automatic centre the stimuli which are needed to keep up the automatism, and that the medulla is incapable of originating the motor impulses unless controlled by afferent stimuli.

What is the function of the pneumogastric in deglutition?

Deglutition both in the pharynx and œsophagus is under the influence of the vagus, which gives innervation directly to the thoracic part of the latter and through the inferior laryngeal branch to the cervical part. The sensory fibres act as conductors of the stimulus which results in the reflex peristalsis by which the food is carried on through the œsophagus. The sensory distribution to the larynx must not be forgotten in this connection, for by it food is kept from the respiratory organs. Section of the vagi causes paralysis of swallowing, and food is apt to pass the glottis on an attempt to swallow, not even a cough being excited by such an accident. The closure of the glottis in swallowing is caused by a reflex action known as the “action of arrest,” and is derived from the sensory fibres of the vagus.

What is the physiological relation of this nerve to the stomach?

Both sensory and motor. The stomach receives its warning of the presence of food through the sensory fibres, and the muscular fibres excite the organ to contract upon it and “churn” it about during digestion. There is also a vaso-motor influence derived from the vagus. When the nerve is cut but little food can reach the stomach because of the paralysis of the œsophagus, and what food does enter is digested very slowly, so that the function of the pneumogastric may be considered essential to stomach digestion. The connection with the solar plexus also involves the intestines in the action of the vagus.

What important excito-motor reflexes depend upon the pneumogastric for one or both stimuli?

Coughing and vomiting, as well as many other less essential reflexes, such as sighing, hiccoughing, and the like.

What is the influence of the vagus upon the heart?

There are numerous branches to the cardiac plexus from the trunk of the vagus and from its inferior laryngeal branch. Stimulation of the pneumogastric nerve diminishes the frequency, or, if strong, entirely stops the heart in diastole. The nerve is therefore regarded as having an *inhibitory* action. This is an unusual effect, for in other cases the stimulation of nerves going to muscles causes contraction: the heart, however, becomes flaccid under the influence of the stimulated vagus.

What is the origin of the spinal accessory or eleventh cranial nerve?

It is twofold. One root arises in the gray matter of the medulla near the nucleus for the vagus, while the others arise from the lateral tract of the cord as low as the fifth or sixth cervical vertebra, and pass up between the anterior and posterior spinal nerve-roots to join the medullary (or accessory) portion at its emergence from the medulla. The united nerve passes out through the jugular foramen with the glosso-pharyngeal and pneumogastric nerves.

How is the nerve distributed?

Soon after leaving the skull it again divides, the medullary root joining the trunk of the pneumogastric, while the spinal root supplies the sterno-mastoid and trapezius muscles.

What is the function of the spinal accessory nerve?

The nerve is a motor to all intents, though it has some sensory fibres, as is shown by the pain caused by pinching it.

(1) *The anastomotic branch*, which joins the pneumogastric, is apparently largely given off in the recurrent laryngeal nerve, but its section does not produce the same effect upon the larynx as section of the trunk of the vagus or of its inferior laryngeal branch. There is paralysis of the voice, but not of the movements of the glottis for respiration. There are probably some fibres of this nerve also given off to the cardiac plexus.

(2) *The muscular branch* supplies the sterno-mastoid and trapezius muscles, but these muscles are also supplied by the cervical spinal nerves, and their action is not paralyzed by the section of this branch of the spinal accessory. It is found, however, that the relation of these muscles to respiration is impaired by isolation from this nerve; that is, when the breath is held in any violent exertion, as straining or pushing, or when a loud cry is uttered,

the sterno-mastoid and trapezius muscles contract to fix the head and hold the spine steady. This action seems to be prevented by the section of this muscular branch of the spinal accessory.

What is the origin of the hypoglossal or twelfth cranial nerve ?

It arises in the gray matter at the inferior extremity of the floor of the fourth ventricle, near the origin of the spinal accessory and pneumogastric nerves. The fibres pass through the substance of the medulla oblongata, skirting (and perhaps gaining fibres from) the olivary body, and, emerging in a number of small bundles, collect into a nerve-trunk which emerges from the skull by the anterior condyloid foramen.

How is the hypoglossal nerve distributed ?

It passes down the neck to about the level of the hyoid bone, where it curves forward and into the tongue, giving off branches to the muscles which move that organ.

What is the function of the hypoglossal nerve ?

It is a motor nerve, but possesses some sensory fibres derived from the cervical spinal nerves and from the trigeminus, with whose lingual branch it inosculates on the side of the tongue. Filaments from it are distributed to all the muscles which move the tongue, and to the depressors of the hyoid bone through its descending branch.

What influence has this nerve upon digestion ?

It is important in mastication, for its muscles move the food about for the better action of the teeth. In animals, after division drinking is impossible, because they are unable to lap up fluids, and the food is swallowed with difficulty because it is not carried back into the pharynx by the tongue after mastication.

What is its connection with speech ?

Articulation of most sounds involves movements of the tongue. Impaired articulation is an early symptom in bulbar or glosso-labio-laryngeal paralysis.

THE SENSES.

What organs are necessary for sensation ?

A peripheral organ for the reception of an impression, a nerve for its conduction, and a centre in the brain for the perception.

It is by means of impressions so received and conducted to it that the mind is able to control the body and to take cognizance of the external world.

Into what classes may the sensations be arranged ?

Common sensations and *special sensations*. These last are commonly called "the senses."

What is meant by the common sensations ?

Such perceptions as cannot be distinctly located in any organ or set of organs, such as fatigue, hunger, thirst, satiety. Besides this, there are some sensations which involve certain organs which must be classed under this head ; thus inclinations to cough or to sneeze or to vomit are common sensations, and, similarly, to urinate or defecate. Many of these sensations occupy a border-line between common sensibility and the special sense of touch, such as itching and tickling.

Is pain a common sensation ?

It is, but is very closely allied to the sense of touch. The two may be differentiated, however. If one touch a sharp instrument, he may perceive its shape and condition, but if the pressure be increased the ability to perceive its form is lost, and instead the sensation of pain is established. The relation of the two is curiously shown in partial anæsthesia by drugs, as when one takes nitrous-oxide gas for the extraction of a tooth, and is able to feel the operation and to know what has been done, without in the least feeling pain.

What is the real seat of the senses ?

The brain or *sensorium*. The organ of the mind, which perceives the thing which the organ of sense has taken an impression from, is the fundamental structure in the necessary chain.

What is hallucination ?

It is the perception of an object as a real presence without the presence of the object to justify the perception ; that is, it is an act of the brain which refers its action to an organ of the senses. Thus, in delirium tremens a person may perceive many curious and uncanny things, which his mind hears and sees and feels, but which his senses could not take cognizance of, because they are only "creatures of the mind."

Do the nerves of special sense possess the property of common sensibility?

No. The special nerves have no other function than the special one for which they are set apart; and when they are separated from their special organs for receiving impressions, they no longer respond to the customary stimuli.

What are the special senses?

Touch, taste, smell, hearing, and sight.

TOUCH.

What is the organ of touch?

The skin and the mucous membranes adjoining it. The nails and teeth too exercise a peculiar function in this regard, and the hair in some regions—*e. g.* eyelashes. The sensations of touch are communicated to the central nervous system through the agency of the sensory nerves of the spinal and cranial systems.

What varieties of the sense of touch are found?

(1) Tactile sensibility, or touch proper; (2) the sense of pressure or weight; (3) the sense of temperature. All of these, when carried beyond moderate limits, are merged into the sensation of pain.

What factors determine the acuteness of touch?

The *distribution of the end-organs* of the sensory nerves varies in different parts of the body, and the more numerous the touch-corpuscles, the more acute the sensibility of the part. Again, the *thickness of the epidermis* has marked influence in determining the tactile ability, portions of the hands and feet, when callous, having very blunted sensibility.

What qualities of bodies are determined by touch?

Their hardness and elasticity, the quality of the surface as to smoothness, the size and form and the temperature and wet or dry condition, are all easily determined by touch.

Why is the hand of especial value as an organ of touch?

Because of the acuteness of its sensibility. Further than this, it is so constructed as to be capable of forming impressions of bodies by reason of its power to grasp them and to test them as to weight.

How is the acuteness of touch measured?

By means of a pair of compasses whose points are blunted. The legs of the instrument are separated, and the distance, between the points which can just be distinguished as two separate contacts, measures the sensibility. From the accompanying table it will be seen that the touch is most acute in the tip of the tongue and in the fingers and tips, while in other portions the sense of touch is so vague that two points of contact are not distinguished until they are $2\frac{1}{2}$ in. apart. It is found that the points of the compasses must be more widely separated when the test is made in the long axis of a limb than when across it. (The table is from Kirke's *Handbook*):

Table of Variations in the Tactile Sensibility of Different Parts.—

(The measurement indicates the least distance at which the two blunted points of a pair of compasses could be separately distinguished.—E. H. Weber.)

Tip of tongue	$\frac{1}{24}$ inch.
Palmar surface of third phalanx of forefinger	$1\frac{1}{2}$ "
Palmar surface of second phalanges of fingers	$\frac{1}{6}$ "
Red surface of under lip	$\frac{1}{8}$ "
Tip of the nose	$\frac{1}{4}$ "
Middle of dorsum of tongue	$\frac{1}{3}$ "
Palm of hand	$1\frac{1}{2}$ "
Centre of hard palate	$\frac{1}{2}$ "
Dorsal surface of first phalanges of fingers	$1\frac{1}{2}$ "
Back of hand	$1\frac{1}{6}$ "
Dorsum of foot near toes	$1\frac{1}{2}$ "
Gluteal region	$1\frac{1}{2}$ "
Sacral region	$1\frac{1}{2}$ "
Upper and lower parts of forearm	$1\frac{1}{2}$ "
Back of neck near occiput	2 "
Upper dorsal and mid-lumbar regions	2 "
Middle part of forearm	$2\frac{1}{2}$ "
Middle of thigh	$2\frac{1}{2}$ "
Mid-cervical region	$2\frac{1}{2}$ "
Mid-dorsal region	$2\frac{1}{2}$ "

How is touch modified by education?

The sense of touch may be greatly educated and specialized. This is seen in many of the arts where great dexterity obtains by reason of an educated touch. The reading raised letters by the blind is a familiar example of educated touch.

What is pressure sensation?

When weight is added to an ordinary touch, the sensation of the pressure of the weight is felt, and by it one can judge with considerable accuracy the amount of the pressure, and determine the comparative pressure of two weights with approximate correctness within limits of pressure. This is known as the sense of pressure.

What is the muscular sense?

By taking a body in the hand and raising it we feel a sense of resistance in the muscles, by whose intensity we can much more accurately determine the weight. This is the muscular sense. It is developed to an exceedingly fine degree in some occupations; for example, postal clerks detect overweight letters with wonderful accuracy and quickness.

What is the origin of the muscular sense?

It has been urged that the muscular sense is of central origin, and depends upon the strength of the impetus which must be sent to the muscles to cause them to do certain work. It may, however, be due to a training of the sensibility of the muscle, whereby the relative strength of a contraction is perceived as a sensation.

What is temperature sense?

The surface of the body is very sensible of temperature changes; and that this is distinct from ordinary tactile sensation has been inferred from the fact that when the ordinary touch is blunted the temperature sense may remain unimpaired.

Are the sensations of temperature accurate from a thermometric standpoint?

No. They are relative; that is, we infer from the temperature of the skin or of our habitual surroundings the warmth or coldness of the thing tested. It is related that Arctic explorers have found the water feel warm when swimming in pools on icebergs, and a drop of the mercury to 80° F. is said to feel cold in torrid climates. A more simple illustration is that of immersing one hand in water at 40° F. and the other in water at 120° F., and then both in water at 80° F., when one hand will feel hot and the other cold, though both are subjected to the same temperature. Again, during a chill the temperature of the body is often very considerably elevated, and yet the sensation is entirely of cold.

May the temperature sense be educated?

Yes. For example, a skilled bath-attendant is able to determine with an astonishing accuracy the temperature of water by immersing his hand.

Does the delicacy of the temperature sense correspond with that of touch proper?

Yes, in the main, but there are some situations in which the skin is very thin, and the temperature sense is relatively much more delicate than the tactile.

TASTE.**What conditions are necessary for the sense of taste?**

Aside from the conditions which are always necessary for sense-perception—viz. proper organs for receiving, communicating, and perceiving the sensory impulse—there must be present a sapid substance which must be in solution. The solution in the case of dry substances is effected by the saliva. It is also necessary that the surface of the organs of taste shall be moist.

Where does the sense of taste arise?

Chiefly from the tongue, though there is some power to taste resident in the soft palate, fauces, tonsils, and pharynx. In the tongue the taste is more acutely developed in the posterior portion, though in most the tip and sides are sensitive to taste. The central portion of the dorsum is not an actively sensitive taste-organ. The under surface of the tongue is little if at all sensitive to taste.

What nervous supply conducts the taste-sense?

Probably the glosso-pharyngeal. The lingual branch of the fifth (or gustatory) is also a conductor of taste-impressions for the front of the tongue.

Describe, roughly, the tongue.

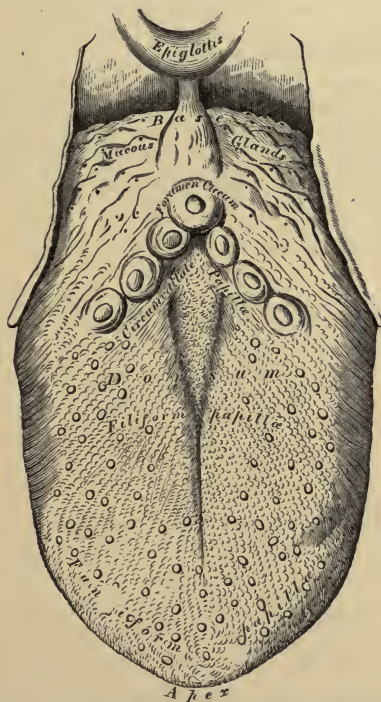
The tongue is a flattened muscular organ covered by epithelium. It is controlled by intrinsic and extrinsic muscles, which give it a remarkable flexibility of movement; the latter for its larger, and the former for its more delicate, actions.

What kinds of papillæ characterize the mucous membrane of the tongue?

There are three varieties found, which are known as *filiform*, *fungiform*, and *circumvallate* papillæ. These are set chiefly upon

the dorsum of the tongue, and over its whole surface are numerous mucous follicles, whose secretions keep the tongue moist (Fig. 41).

FIG. 41.



Upper Surface of the Tongue.

Describe the filiform papillæ of the tongue.

The *filiform papillæ* are set mostly upon the middle of the dorsum, but are scattered over the entire surface, and are far more numerous than any other kind. They are conical in shape, and are covered with epithelium, which projects in a brush-like tuft from the apex. Their function is mostly tactile, and in animals, especially of the cat tribe, are very prominent.

Describe the fungiform papillæ.

They are chiefly distributed over the sides and tip of the organ, and sparsely upon the dorsum. They are larger at the surface than at the base, club-shaped, and are supplied with blood-vessels and nerves. Their function is probably sensory.

Describe the circumvallate papillæ.

They are somewhat similar in shape to the fungiform, but considerably larger. They are situated at the posterior portion of the dorsum in a V-shaped arrangement, and number only eight or ten. In the circumvallate papillæ are the *taste-goblets*, or gustatory buds, which are the form of nerve-ending characterizing the parts where this sense is developed.

What other functions are dependent upon the tongue besides taste?

The sense of touch is very highly developed here, and with it the sense of temperature, pressure, pain, etc.: upon these touch and muscular senses to a great extent depend the accuracy of the tongue in many of its important uses—speech, mastication, deglutition, sucking. The tactile sense is very important, too, in the sense of taste, for with many substances the taste is largely due to their mechanical condition: this is the case with mucilaginous, oily, and chalky tastes.

What relation has the sense of smell to taste?

It is important, for with many substances—particularly aromatic substances—of food and drink the association of smell and taste is very essential to a thorough appreciation of a flavor. Most cooked foods lose their savor if the nose is obstructed; thus with a “cold” in the nose “everything tastes alike.”

What kinds of flavors are appreciated by the tongue?

The principal tastes are sweet, bitter, acid, alkaline, and saline. Besides these, the general sensibility of the tongue detects pungent or caustic and styptic tastes, as well as the oily and mucilaginous tastes.

What degree of taste-sensibility has the tongue?

It is quite acute. A solution of acid or bitter substances is tasted when very dilute: strychnine is said to be tasted in a 1 : 600,000 solution; sulphuric acid, 1 : 1000.

What is after-taste?

After an aromatic substance has been tasted there remains in the mouth an impression of that flavor, and if such substances be taken in rapid succession, the appreciation of their flavor is lost. This impression, which is left by a strong flavor, is called the after-taste, and is utilized sometimes to cover the taste of a disagreeable medicine, a strongly-flavored aromatic preceding it.

What influence upon taste has the muscular action of the tongue?

Twofold. It breaks the food up more thoroughly by its pressure against the walls of the mouth, and so brings it into a better condition to reach the nerve-endings; and it carries the food about the mouth, so that the taste-organs are able to reach it readily.

SMELL.**What are the conditions necessary to the sense of smell?**

The special organs for this sense for the reception, conduction, and perception of the stimulus, as in the case of any of the senses, must be in their proper condition, and a stimulus (an odor) must be present to excite them.

What are odors?

They are caused either by minute particles of solid matter or by gases which are in the atmosphere, and they must be capable of *solution* in the mucus of the Schneiderian membrane. The substance must pass in a current of air through the nostrils or it is not perceived as an odor. This is accomplished by "sniffing" the air, and thus creating an intermitting current which is tested by the olfactory sense. In this way a trace of a gas or impalpable powder may be detected which cannot be traced by chemical or other means. If the substance be applied as a solution, it is not detected; thus, rose-water in a nasal douche is not noticed while the nostrils are full of fluid, and yet as soon as the nostrils are free the odor appears.

Where is the organ of the sense of smell?

In the mucous membrane of the upper part of the nasal cavity. The olfactory nerves are the functional nerves of the sense, and are spread out in a fine network (Fig. 42) over the surface of the superior or turbinated bone and upper portion of the middle turbinated bone, and on the upper third of the septum. The nerves end in

FIG. 42.



Distribution of Nerves in the Nasal Passages: 1, olfactory bulb, with its nerves; 2, nasal branch of the fifth pair; 3, sphenopalatine ganglion.

special end-organs, known as *olfactory cells*, which lie under the ciliated epithelium of the part.

Describe the origin of the olfactory nerves.

The nerves arise from a mass of gray matter lying beneath the anterior lobe of the brain upon the cribriform plate of the ethmoid bone. This is the olfactory bulb, and it is connected by the olfactory tract with the cerebrum.

Is tactile sensibility a property of the olfactory nerve?

No. The lining membrane of the nasal cavity is very sensitive to irritation, but the nasal branch of the fifth nerve and branches from the sphenopalatine ganglion furnish the ordinary and tactile sense.

Do the perceptions by the olfactory and by the nerves of touch resemble each other?

Often they do, and some stimuli affect both nerves. The common sensibility is evoked by such substances as are irritating and acrid: ammonia gas has no odor, but it stimulates the mucous membrane by its irritating properties. The tactile or common sensibilities remain when the olfactory are gone. The relation between

the two kinds of perception is lost to us, and we speak of the smell of ammonia or of alcohol when it is probably not an olfactory, but a sensory, perception.

Is the sense of smell very acute?

Yes, but not so sharp in man as in many of the lower animals. The distribution of the olfactory nerves is much wider in some of the animals, and the cerebral development is correspondingly increased. In man the range of susceptibility is, however, probably greater. The variety of odors and the very minute quantity of stimulant substance required to produce a sensation of smell are quite wonderful. The most delicate analysis may fail to show traces of the substances which can be appreciated by the sense of smell.

Is the same odor agreeable to all men?

No. There are some odors pleasant to some which others find almost intolerable. Musk, for example, is a pleasant perfume to some, while to others it is quite unendurable. In the same way, the acuteness of this sense in some is more marked than in others, and yet this may apply only to certain kinds of odors.

Is sneezing a reflex from the olfactory nerve?

No. It is excited through the fifth.

Are hallucinations of smell common?

They often occur, and in cases of disease of the olfactory centres there is often complaint of a constant bad smell. With normal organs there may be a sensation of an odor which cannot be detected by others present.

HEARING.

How does the auditory or eighth cranial nerve originate?

The fibres arise from a nucleus of gray matter in the floor of the fourth ventricle, and from this source pass out through the substance of the medulla in a number of small bundles which unite with another root from the *cerebellum* to form a trunk. This passes with the facial nerve into the internal auditory canal, and terminates in special end-organs in the internal ear.

Describe, roughly, the auditory apparatus.

It consists of (1) the external ear; (2) the middle ear; and (3) the internal ear.

What is the function of the external ear?

It serves to receive the sound-waves and to indicate the direction from which they come in animals who possess the power of moving the organ. Through the external auditory canal the sound-waves are conducted to the middle ear.

Describe the middle ear.

It is a cavity in the temporal bone which is shut off from the external auditory canal by the tympanum. The Eustachian tube connects this cavity with the pharynx. The lining of the middle ear is ciliated epithelium, continued from the mucous membrane of the pharynx through the Eustachian tube. There are two openings of importance—the fenestra rotunda and the fenestra ovalis—in the bony wall, but they are covered, the former by membrane, the latter by the stapes. There is a chain of small bones (ossicles) which connect the tympanum and the fenestra ovalis.

What is the tympanum?

It is a tough, tense, fibrous membrane set in the bony opening of the external auditory canal. The degree of tension of the tympanum is regulated by the tensor tympani muscle.

Fig. 43.



Right Temporal Bone of the New-born Infant, seen from its inner side, showing the membrana tympani and chain of bones in their natural position (Rüdinger).

What is the function of the ossicles?

They are three in number, and are so articulated as to commu-

nicate the vibration of the tympanum to the internal ear (Fig. 43). The handle of the malleus is attached to the tympanum, so that this bone moves with each vibration. This motion is communicated to the incus, which passes it on to the stapes. The stapes forms a sort of piston in the foramen ovalis, and is therefore capable of transmitting to the fluid in the cavity of the labyrinth the impulses which it receives.

Describe the arrangement of the internal ear.

The internal ear, or labyrinth, is situated in the dense petrous portion of the temporal bone, and consists of three essential parts: the vestibule (Fig. 44), and opening from it the semicircular canals and the cochlea. There is another opening, the *æqueductus vestibuli*, whose use is unknown, and still others for the entrance of the auditory nerve-filaments. Within the bony structure is a membrane of fibrous and epithelial tissue, the membranous labyrinth, which follows the bony structure and contains a colorless fluid, the endolymph, and a fluid surrounds this membranous labyrinth, the perilymph.

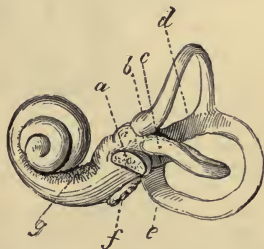
What is the function of the semicircular canals?

These canals are arched cylindrical spaces in the solid bone which open at each end of the arch in the vestibule. They are three in number, and two are nearly vertical and one is horizontal. These canals are arranged in such a manner that the planes of the two vertical canals are at right angles, one being fore and aft, and the other transverse (Fig. 44). Their use does not seem to be directly connected with the auditory function of the part, but to be connected more with the sense of *equilibrium*. The movement of the fluids in the canals, arranged in the directions of the three dimensions, may serve to produce sensations which lead to the formation of accurate judgment of changes in the position of the body.

What is the cochlea?

It is a part of the labyrinth which derives its name from its

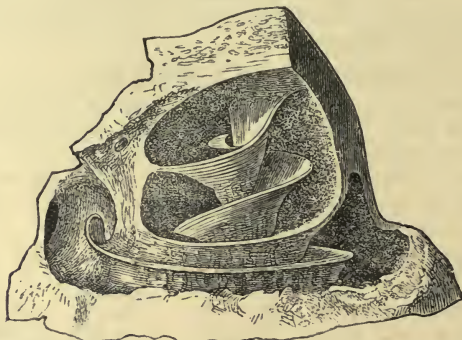
FIG. 44.



External View of a Cast of the Left Labyrinth (Henle): *f*, fenestra cochleæ, or round window; *a*, fenestra vestibuli, or oval window; *b*, ampulla of superior semicircular canal; *d*, common shaft of union of these two canals; *e*, ampulla of the horizontal semicircular canal; *g*, tractus spiralis foraminosus.

resemblance to a snail-shell. It is divided into two parts, by bony and membranous structures, which run parallel from base to apex of the spiral (Fig. 45). The upper passage opens into the vesti-

FIG. 45.



Bony Cochlea of the Human Ear, right side, opened from its anterior face (Cruveilhier).

bule, and is known as the scala vestibuli; the lower, the scala tympani, is shut off by a membranous partition, which covers the foramen rotundum, from the cavity of the tympanum. The scala vestibuli is subdivided by a fibrous membrane (of Reissner) which passes from the bony lamina spiralis to the wall of the scala vestibuli, shutting off a triangular space (canalis cochlearis). The floor of this space is the membranous partition (membrana basilaris) which separates the scala tympani from it, and upon this membrane is the *organ of Corti*.

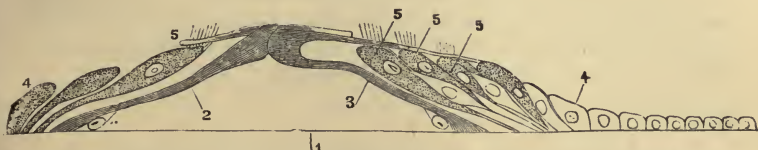
What is the function of the cochlea?

It is to spread out, over as large a surface as may be, the mechanism for the reception of sounds by the organ of Corti, the end-organ of the auditory nerve. It seems to be especially well adapted for this purpose, because the solid spiral lamina connects it with the bony framework of the skull, while it is contained in the membranous labyrinth, whose fluid contents fit it for the response to vibrations. It is further insulated by its suspension in the perilymph. These peculiarities favor the conduction of semi-vibrations through the bone, as well as of vibrations through the mechanism of the middle ear.

Describe the organ of Corti.

Upon the basilar membrane is arranged a series of rafter-like bodies which roof in a small canal (Fig. 46): upon this are spread

FIG. 46.



Diagrammatic Section of the Organ of Corti: 1, membrana basilaris; 2, 3, internal and external fibres of the arch; 4, epithelium cells near its inner and outer borders; 5, Hair-cells lying in contact with the arch (magnified 500 diameters).

the functional nerve-endings of the auditory nerve. They are large nucleated cells, the rods of Corti, having hair-like processes which project into the canalis cochlearis or scala media. When looked at from above the cells have an appearance similar to the keyboard of a piano. Fibres of the auditory nerve spread to these cells from the bony lamina spiralis.

What peculiarity of structure of the auditory nerve is noteworthy?

Its fibres are non-medullated, and it contains numerous ganglion-cells. In the cochlea there are many of these cells, and they form plexuses of nerve-fibres to supply the hair-cells. The absence of neurilemma in the auditory nerve gives it a soft feel which has caused the name "*portio mollis*" to be given to it when it and the facial are considered as a single nerve.

What is the physiological action of the organ of Corti?

It is probable that each of the functional cells in the organ of Corti responds to a particular shade of sound. How this occurs is not understood, but the vibrations of the tympanum are communicated to the stapes by the other ossicles; and these cells seem to be able to respond each to a particular tone by its sensitiveness in selecting its particular rate of vibration.

What is the musical range of human hearing?

About seven octaves. There are about three thousand hair-cells in the organ of Corti, and it will be easily seen that this would allow an enormous capability to differentiate sounds and musical tones.

What subjective sensations of hearing occur ?

They may be due to disturbances of the auditory apparatus or to abnormal conditions of surrounding organs. Thus, buzzing or ringing in the ears may result from the hyperæmia of the parts and exaggerated rush of blood, or from a defect in the circulating apparatus (as by an aneurism), or from disease in the auditory nerve or some other portion of the apparatus. Hallucinations of hearing are very common among the insane.

How is the voice produced ?

The vibration of the vocal cords is produced by the passage of the air in expiration, never naturally in inspiration. The quality of the voice as regards pitch depends upon the length of the vocal cords, the crico-thyroid muscles acting to increase the tension, while the thyro-arytenoid relax the cords and the crico-arytenoids dilate and contract the rima glottidis. Falsetto and high-pitched notes in a naturally low-pitched voice are due to vibration at the edges of the cords. The hollow spaces about the oral and nasal cavities are of use as resonators or sounding-boards.

What organs are used in the formation of articulate speech ?

The tongue and teeth in the formation of the linguals and dentals, the nasal sounds by the cavity of the nose ; the other sounds are formed largely by modifications in the shape of the mouth in one or another part.

What range has the human voice in respect of pitch ?

From one to three octaves : in this cultivation and natural aptitude are factors which permit great variability. The total range of the human voice from the highest soprano to the lowest bass is about four octaves. Thus it will be seen that the range of sounds which can be appreciated by the ear is far beyond the capacity of the voice.

SIGHT.**What is the function of the eye ?**

The reception of stimuli of light, whereby we are able to perceive the impressions of form, color, and conditions of our surroundings in infinite variety. It is far the most complex in structure of any of the organs of special sense, and the most rapid and delicate in its actions.

What is the origin of the optic or second cranial nerve?

It arises by two roots—one in the corpora quadrigemina, and the other in the optic thalamus—with many fibres derived from centres of vision in the posterior portion of the cerebral lobes. These fibres unite and form a nerve-trunk (the optic tract) which encircles the crus cerebri, meeting the tract of the opposite side just in front of the pituitary body. Here there is a fusion of the two optic tracts in a partial decussation, some fibres going to the eye of the same side, and some decussating. The fibres then pass to each eye as the optic nerve, which is distributed by special nerve-endings in the retina.

Has the optic nerve any other physiological property than that of conduction of special-sense impulses?

No. It has no common sensibility. It is, however, the conductor of afferent impulses for the iris reflex.

What is the effect of stimulation of the divided optic nerve?

None, for the peripheral end; for the central portion, a sensation of light and contraction of the pupil.

What accessory apparatus is important to the protection of the eye?

Eyelids and lachrymal gland.

Describe the eyelids.

Each eye has two lids, an upper and lower. Each consists of a thin plate of elastic tissue with a covering of loose skin and a smooth lining of mucous membrane—the conjunctiva—which is reflected upon the eyeball. Along the edges of the lids are a number of short curved hairs which screen the eye from foreign bodies. The extreme sensitiveness of the conjunctiva helps in this by giving immediate warning when any foreign substance gets in the eye.

What is the lachrymal gland?

It is a small racemose gland lodged in the upper and outer part of the orbit. It has several ducts, which lead to the surface of the conjunctiva of the upper lid. The secretion of the gland is usually just sufficient to keep the eye moist, but under the stimulus of pain or intense emotion the secretion is increased, and appears in drops which flow from the eyes—tears. Under ordinary circumstances a slight excess of this moisture is drained into the

nasal cavity by the lachrymal duct. This secretion is slightly alkaline, and contains about 1 per cent. of solids, chiefly sodium chloride.

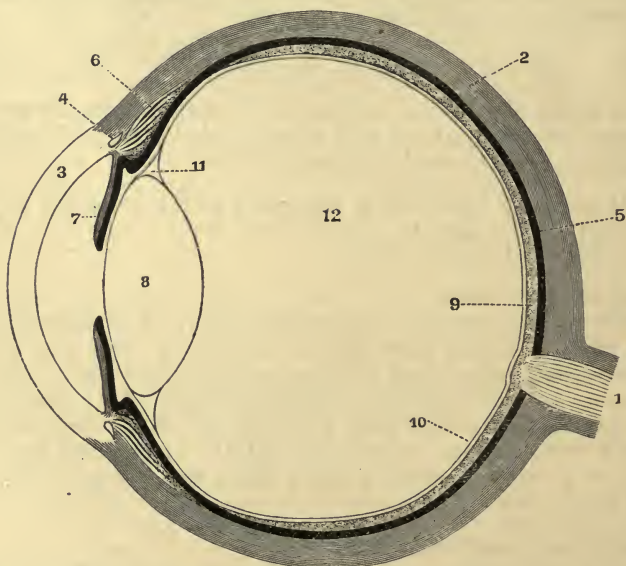
What are the Meibomian glands?

They are a number of small racemose glands, lying beneath the conjunctiva, which secrete an oily protective substance. The ducts of these glands open along the edge of the lid.

Describe the eyeball.

It consists of a tough, opaque *globe* (Fig. 47), having a some-

FIG. 47.



Horizontal Section of the Right Eyeball: 1, optic nerve; 2, sclerotic coat; 3, cornea; 4, canal of Schlemm; 5, choroid coat; 6, ciliary muscle; 7, iris; 8, crystalline lens; 9, retina; 10, hyaloid membrane; 11, canal of Petit; 12, vitreous body.

what more sharply-curved translucent portion, the cornea, at the front. It has in the anterior portion a *lens*, and in front and behind this are chambers which contain fluids: the one in front is

the *anterior chamber*, and contains the aqueous fluid, while the posterior is the *vitreous humor*. These structures fill the eyeball and give it a tense feel to the touch.

What are the coats of the eyeball?

(1) The *sclera*, or *sclerotic coat*, is external, and covers about five-sixths of the globe. The cornea is continuous with it in front. It is composed of tough white fibres arranged in intercommunicating layers. (2) The *choroid* coat is very vascular, being composed of a mesh of capillaries. There is outside of this a layer of connective tissue containing pigment-granules. (3) The *retina*, which is the seat of the end-organs of the optic nerve.

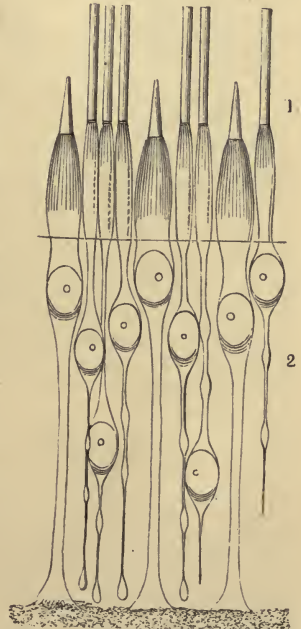
Describe the retina.

It consists of the *nervous mechanism* of the eye lying in a loose connective tissue, and beneath it a *pigment-layer*. Without entering into the details of its numerous layers, we may say that the fibres of the optic nerve spread out, divested of neurilemma, in this membrane, and communicate with ganglion-cells, which are abundant. The fibres pass inward and terminate in the layer of *rods and cones* which form the end-organs of the nerve.

Describe the rods and cones of the retina.

They are closely packed at the surface of the retina, the rods being the more numerous in most situations. The cones seem to be modifications of the rods, and their office is essentially similar. The *rods* (Fig. 48) are straight cylindrical bodies of a transparent substance, and are placed parallel to one another and perpendicular to the surface of the eyeball. In length they are about five to seven times the diameter of a red blood-corpuscle, and in diameter about

FIG. 48.



Diagrammatic Section from the posterior Portion of the Human Retina: 1, layer of rods and cones; 2, layer of nuclei (Schultze).

one-twentieth of their length. The *cones* are very similar, except that their conical shape makes them appear to be of different character. The cones do not always reach to the same level as the rods. When viewed from the retinal surface, the ends of the rods and cones give the appearance of a fine mosaic. These organs are connected with the subjacent nervous tissue, but the mode of their connection with the optic nerve is not fully understood.

Considered as an apparatus, how is the eye arranged?

It may be compared to the photographic camera. It contains various media for the refraction of light, and a screen at the back for receiving the image. The refracting media are the cornea, aqueous humor, crystalline lens, and the vitreous humor: the screen is the retina. The pigment of the retina and choroid makes the interior dark, a necessary feature in such an apparatus. The mechanism of the lens enables the eye to be focused for distance, while the iris regulates the proper admission of light.

What is the structure of the cornea?

It is continuous with the sclera in the front of the eye, and occupies about one-sixth of the surface (3, Fig. 47). Its shape is that of a small dome set upon the globe of the eye. It has in front several layers of epithelial cells, and at the posterior surface a thin epithelial lining (membrane of Descemet); but the main body of the structure consists of interlacing connective-tissue fibres, which have spaces in which are found branching cells peculiar to the structure. The cornea is perfectly transparent: it has no blood-vessels.

Describe the crystalline lens.

It is a double convex lens (8, Fig. 47) of high refractive power which is suspended in the anterior portion of the eye immediately behind the anterior chamber. Its function is to bring the rays of light to a focus upon the retina. In structure the lens is composed of concentric layers of long, slender fibres enclosed in a thin capsule.

What are the aqueous and vitreous humors?

(1) The *aqueous humor* is a watery fluid contained in the anterior chamber. It acts with the cornea as a refracting medium to concentrate rays of light upon the lens, to maintain the globular form of the cornea, and to float the iris and allow it freedom of motion.

(2) The vitreous body (or humor) is a semifluid gelatinous substance which fills the posterior chamber and constitutes about four-fifths of the bulk of the eye. It is quite transparent, and acts to maintain the tension of the eyeball, and as a refracting medium through which the light reaches the retina.

What is the pupil?

The pupil is the aperture through which light enters the dark chamber of the eye. It is a circular opening in the iris.

What is the iris?

It is a curtain of muscular tissue placed vertically in front of the lens. The fibres of the muscular tissue are both circular and radiating, so that they serve to decrease and increase the size of the pupil as one or the other set of fibres acts. It has a pigment-layer upon the inner surface, which is continued from the choroid, and upon the amount of the coloring-matter depends the "color of the eyes."

What nervous action controls the ciliary muscles?

Contraction or dilatation of the pupil is a reflex act, and the afferent stimulus is carried through the optic nerve and the motor through the third cranial nerve, acting from a centre just beneath the aqueduct of Sylvius and the corpora quadrigemina. The increase in the amount of light which reaches the retina causes a contraction of the pupil, and a decrease is followed by dilatation. Aside from this, the needs of the eye regulate the amount of light; thus, for near work the pupil contracts, and dilates when the eye is focused upon a distant object.

What other influences control the iris?

The pupil is controlled also through the sympathetic, and the fifth nerve through the connection of the third and fifth nerves with the ciliary ganglion of the sympathetic system. Drugs are active also, both locally and internally, in controlling the action of the iris without reference to the reflex fibres: atropine both locally and internally dilates the pupil; opium internally, and eserine locally contract it.

What is accommodation in vision?

The eye is able to see objects close at hand and at a distance with equal clearness, though perhaps not with equal regard for the

minuter details. This is known as the accommodation of the eye. In optical instruments this process of accommodating the instrument to the focal distance is called focusing. So is accommodation an automatic focusing of the eye.

How is accommodation effected?

By the ciliary muscle. The crystalline lens is suspended in its capsule by the suspensory ligament, and this is controlled by the ciliary muscle. At rest the eye is focused for seeing at a distance, and the lens is held somewhat flattened by the tension of the suspensory ligament. When focusing upon a near object the ciliary muscle contracts, and the lens is permitted to project more as the tension of the ligament relaxes.

What is the near-point?

It is the nearest point to the eye at which vision is distinct, the shortest focus of the crystalline lens. It is usually about 5 or 6 inches.

What is an emmetropic eye?

It is the normal eye; that is, an eye in which parallel rays or rays from objects at a distance are focused upon the retina without an effort at accommodation. Such a distance, for practical purposes, is considered to be any point beyond 20 feet. Absolutely emmetropic eyes are not common.

What is myopia?

Near-sight. In this case the rays from a distance are focused in front of the retina, and the image is blurred. Such an eye is permanently focused for near objects.

How is myopia produced?

In two ways, by the antero-posterior diameter of the eye being too great, or by the convexity of the lens being exaggerated. In either case the focus of the lens will fall in front of the retina.

How is myopia corrected?

By the use of a concave lens which diverges the rays, and in this way prevents their coming to a focus too soon. Such glasses are seldom needed except for distant vision.

What is hypermetropia?

Far-sight. In this case the lens focuses *behind* the retina in

near vision, and the image is blurred as in myopia for distant vision.

What are the causes of hypermetropia ?

Shortening of the antero-posterior axis of the eye or abnormal flattening of the lens, which does not allow accommodation for near vision.

How is hypermetropia corrected ?

By the use of convex lenses, which add to the refractive power of the eye.

What is astigmatism ?

A defect in the vision due to the irregularity in the globe of the eye, whereby the diameter in one plane is greater than in another. Thus, the retina may be an uneven surface, and the image focus accurately in one part and falsely in another. In this condition vertical and horizontal lines are not seen with equal distinctness.

How is astigmatism corrected ?

By the use of cylindrical or prismatic glasses, which have to be accurately adapted to the needs of each case. This error, if serious, is usually combined with other defects of vision, frequently myopia.

What is presbyopia ?

Defective vision due to the loss of power in advanced years. The elasticity of the lens becomes less, and the convexity cannot be increased for near vision. The ciliary muscle may also be weaker and aid in the production of the error. A weak convex glass commonly corrects the lack of refraction-power.

Is the eye achromatic ?

Yes. It may, however, be said that there may be a visible band of color seen by some defective eyes where there is considerable fault in the focus of the image on the retina.

What is the "blind spot" ?

The point of entrance of the optic nerve is not sensitive to light, and at this point an image thrown upon the retina is not seen ; therefore it is called the blind spot.

How is the blind spot demonstrated ?

If the left eye is covered and the right directed steadily upon

the cross in Fig. 49, the circular spot will be visible at the same time, though less distinctly. As the book is moved slowly backward and forward, a point will be found at which the round spot

FIG. 49.



disappears, reappearing as the book is held nearer or farther or as it is inclined in either direction and the image is carried away from the blind spot.

What part of the retina possesses the most acute vision?

The portion directly behind the lens, where the macula lutea (yellow spot) with its central depression (fovea centralis) is situated. Here are found none of the fibres of the optic nerve, but a great increase in the number of the cones of the layer of rods and cones, as well as an increase in their size. In looking at any object it is upon this spot that its image is reflected by the media, and here the power of the end-organs of the optic nerve is most highly developed.

What conclusion is drawn from these facts?

That the rods and cones (more especially the cones) are the physiological agents for the reception of light stimuli; for upon the blind spot is no layer of the rods and cones, while in the point of sharpest sight the nerve-fibres are wanting, and these elements are especially prominent.

What is the duration of visual sensations?

The duration of a visual sensation is always greater than that of the stimulus which has caused it. However brief the luminous impression, the effect on the retina lasts about one-eighth of a second. The spokes of a rapidly-revolving wheel for this reason do not appear as spokes, but as a solid mass, each following one another so rapidly that one impression cannot fade before another has replaced it.

What is the retinal red?

When the retina of a recently-killed animal is examined it is colorless, but during life or if extracted without exposure to light, it is of a purple-red hue, and the color is found in the rods of the retina. It is derived from the pigment of the deeper part of the retina. It is the "retinal red" or "visual purple," as it is variously named, which one sees in the *reflex* of the retina.

What effect has exposure to light upon the retinal red?

It destroys it, and for this reason it was long unknown. It disappears after a brief exposure to sunlight, about half a minute.

How may the retinal red be seen?

By throwing a beam of light into the eye by a mirror, as by the ophthalmoscope, a red glow is observed in the pupil. This is called the *retinal reflex*.

What are optograms?

Pictures which appear upon the retina after exposure to light. They are due to the fact that an exposure to light bleaches the retinal red, leaving it dark in the shaded portions.

How are optograms obtained?

The eye is removed from an animal in a dark room and kept in a covered box until exposed to a brightly illuminated skylight or window for some minutes. The eye is then replaced in the dark room and the retina examined. It will be found that the panes of the window are shown in light color, while the sash is in dark outline. This soon fades on exposure to daylight, but if the retina is dried in the dark the optogram is much more durable.

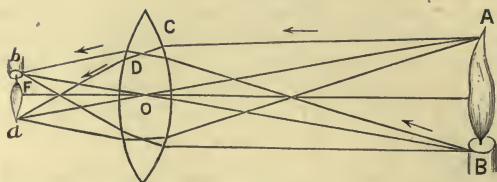
Is the pigment of the retina essential to vision?

No, but it is of considerable use in rendering the eyeball a dark box, which is of importance here as in all optical instruments.

How is the real image formed by a double convex lens?

It is an inverted image at the point of focus of the lens if the luminous object is placed at a distance (Fig. 50). Referring to this figure, it will be seen that the rays originating at A will be twice refracted, once by the lens and again in leaving it, so that all rays from A reaching the lens are joined at *a*. The same is true for B and *b*. Therefore a screen placed at the focus, F, will receive an inverted image, *a b*, of the luminous object, A B.

FIG. 50.



Formation of Image by Convex Lens.

Does the crystalline lens throw an inverted image upon the retina?

Yes. This may easily be demonstrated by looking at the image from behind a fresh eye of an albino animal (white rabbit) or if the sclera be thinned.

How is this inversion corrected?

The correction is made by the brain in its *perception* of the image. It is an act of mental and not of physical origin. Thus, objects which are projected upon the left of the retinal surface *look* to be, as they are, on the right of the body; and so with all the directions: the inversion of the retinal image is corrected by the mind.

What other visual perceptions are the result of mental processes?

We are able to estimate by the aid of the brain the size, direction, distance, form, and speed of motion of a thing which we have seen. All of these are judgments based largely upon previous experience. All of these deductions are liable to error by reason of faulty judgment or faulty vision, but this is the usual method of forming such estimates.

How does the eye perceive colors?

It is probable that particular rods and cones are capable of responding to rays of light of a certain wave-length, and to those rays alone. It is well known that the rays of red light are of a certain length of vibration. The same is true of yellow and of green rays. We can conceive that each primary color has its own set of cones and rods capable of responding to its stimulus, and that by combinations of these stimuli the complementary colors and variations of shade may be perceived by the resulting stimuli acting upon the brain-centres. Such teaching is, of course, speculative, but this is one theory which has acceptance.

What is color-blindness?

An inability to perceive some colors. The colors which are usually mistaken are green and red. Frequently it is found that a distinction cannot be made between these colors. This is sometimes known as Daltonism.

What is the cause of color-blindness?

It is probably due to the absence of the rods and cones which are capable of responding to the stimulus of rays of a certain wavelength.

Is this an important defect?

Yes. In marine and land locomotion red and green signals are used to indicate opposite conditions, and the failure to distinguish them has frequently been the cause of serious accidents.

How is color-blindness tested?

By laying a number of skeins of yarn of various colors in a heap, and requiring the person to be tested to select all resembling a certain skein from the heap.

Do the eyes act both at once, or do we see with one at a time?

We use both in ordinary vision at the same time.

What is diplopia?

It is the condition which results from a want of harmony in the eyes, so that the image of each eye is perceived separately; that is, one sees double.

What are the common causes of diplopia?

Paralysis or spasm in one of the lateral straight muscles, which does not allow the eye to be turned in harmony with the other. If the eyes are turned so that the axes of vision are separated, the condition is known as external strabismus or squint; if the axes are crossed, it is called internal strabismus or cross-eye.

What benefits result from binocular vision?

The ideas of form and distance are much more correctly judged by the perceptive faculties. This is due to the fact that the object viewed is seen beyond its equator, so to speak, by each eye, and the combined image is therefore less flat in appearance than in monocular vision.

What instrument is devised to take advantage of this?

The stereoscope. In this instrument two photographs are taken by cameras so placed as to represent the position of the eyes in vision, and the two views of one object are then superimposed by the use of prisms.

What determines the clearness of vision?

The space between the cones in the point of clearest vision, the macula lutea. It has been calculated that an object must subtend an arc of at least 60 to 70 seconds in the field of vision to be clearly seen. Such an object makes an image of about $\frac{1}{12000}$ * of an inch in the retina; and this is about the distance between the cones at the macula lutea. Similarly, two points to be clearly distinguished must be separated sufficiently to allow this amount of separation in the retinal image.

What are after-images?

It has already been noted that vision lasts longer than the stimulus which excites it. Under some conditions it may last a perceptibly long time: it is then known as an after-image. If one looks at an intense light, the sun, the sense of light remains for some time in the eye. Similarly, if one looks intently at a white spot on a black background, and then turns to a white surface, one has the image of a gray spot. The first of these conditions cited is known as a positive after-image, and the latter as a negative. In the first case the phenomenon results in a continuation of the same sensation, and in the latter a new perception results.

What peculiarity do the after-images of colored objects present?

They appear to have the complementary color of the original object; thus, green excites a reddish after-image; orange, blue; and so on.

How are after-images explained?

They may be explained as a result of exhaustion. The part of the retina on which the image has fallen becomes tired, and when the eye is turned upon a white ground, the white light coming to the retina does not produce as much sensation in the tired portion. The colored negative after-images may be similarly explained.

* Various estimated at $\frac{1}{12000}$ to $\frac{1}{3000}$ of an inch.

EMBRYOLOGY.

REPRODUCTION.

What is a species?

It is a class of organized beings in which the individuals composing it die off, but which nevertheless repeats itself and maintains its complement by the continued accession of similar forms.

What is reproduction?

It is the process by which a species is perpetuated, notwithstanding the limited existence of the individual members.

What law governs the reproduction of species?

The young are of the same kind as their parents. By this law, which is so commonly observed as to seem a truism, is maintained the anatomical identity of individuals of a species, as well as the physiological fact of an unbroken continuance of the species by reproduction.

What is sexual generation?

It is reproduction of a species by a union of elements produced separately by the female and the male. The female produces the *ovum* or egg, which is capable of being developed into a living offspring only when it is fecundated or impregnated by the *seminal* or spermatie element from the male.

What are the organs of generation of the female?

They consist of two *ovaries*, in which the ova are formed, and their oviducts or *Fallopian tubes*, which carry the ova to the *womb*, in which they may develop if fecundated by the male; and the vagina for the reception of the male organ in *copulation* and for the subsequent discharge of the *fœtus* (Fig. 51).

Describes the ovaries.

They are two organs lying one on each side of the uterus, in the folds of the broad ligament. In size they are about $1\frac{1}{2}$ in. long, 1 in. wide, and $\frac{1}{2}$ in. in thickness. Besides lying between the layers of the broad ligament, they are stayed in their position by an attachment to the fundus of the uterus and to the fimbriated extremity of the Fallopian tube.

What is the minute structure of an ovary ?

It may be described as a ductless gland in which the component elements are (1) a stroma of connective tissue and unstriated mus-

FIG. 51.



Generative Organs of the Human Female: *a, a*, ovaries; *b, b*, Fallopian tubes; *c*, body of the uterus; *d*, cervix; *e*, vagina.

cle-cells, and with them a great number of peculiar spindle-shaped branching cells; and (2) the glandular portion, characterized by the Graafian follicles.

What are the Graafian follicles ?

They are best observed during the childbearing age. They lie in the periphery, and present various appearances as they are more or less matured. Some are large enough to be seen by the unaided eye, while others are very minute. In the matured follicle the interstitial tissue will be found to have collected in a wall, quite well defined, which is lined by an epithelial layer; and upon one side this epithelium is heaped up into a mass, the *germ-hill* (cumulus proligerus), which contains the ovum. The remainder of the follicle is filled with a colorless fluid.

How does the ovum leave the ovary ?

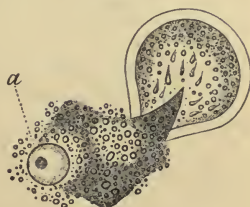
As the Graafian follicles mature, they approach, and often pro-

ject above, the surface of the ovary. The fluid contents of the follicle increases and the wall becomes thinner over it, until finally it bursts, and the ovum with some of its surrounding epithelium escapes.

What peculiarity of the ovary favors the escape of the ovum?

The ovary is covered with a thin layer of epithelium (*the germinal epithelium*), and not by the serous membrane which lines the abdominal surfaces of the rest of the viscera. This is of great importance in the life of the ovum, for it renders it possible for it to enter the orifice of the Fallopian tube without interfering with the peritoneum and without having to pass so dense a structure.

FIG. 52.



Human Ovum, ruptured by Pressure, showing the vitellus partially expelled, the germinal vesicle, with its germinal spot, at *a*, and the smooth fracture of the vitelline membrane.

FIG. 53.



Section of the Ovary (after Schrön): 1, outer covering; 1', attached border; 2, central stroma; 3, peripheral stroma; 4, blood-vessels; 5, Graafian follicles in their earliest stage; 6, 7, 8, more advanced follicles; 9, an almost mature follicle; 9', follicle from which the ovum has escaped; 10, corpus luteum.

Whence is the ovum derived?

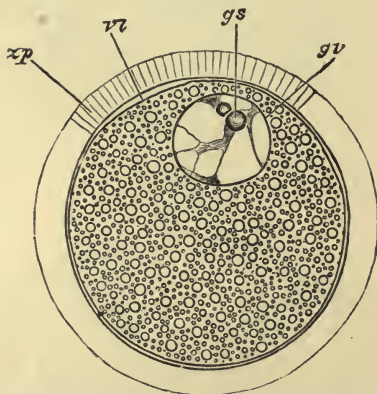
It is a very highly developed cell, which is derived from the germinal epithelium covering the ovary. In the development of the ovary this epithelium dips into the surface of the organ, and a

certain portion is finally walled off by growth of the surface cells. Thus a ball of epithelial cells is introduced into the body of the organ, and one cell develops the ovum, the rest going on to make up the Graafian follicle and the germ-hill. (See 5, 6, 7, 8, 9, Fig. 53.)

Describe the ovum.

It is a minute globular cell containing a nucleus and nucleolus. In diameter it is a little less than $\frac{1}{100}$ in. (Fig. 54).

FIG. 54.



Semi-diagrammatic Representation of a Mammalian Ovum, highly magnified: *zp*, zona pellucida; *vi*, vitellus; *gv*, germinal vesicle; *gs*, germinal spot.

What is the zona pellucida or vitelline membrane?

It is a thick hyaline membrane (cell-wall) which encloses the cell.

What is the vitellus?

It is a granular protoplasm which makes up the cell-body.

What is the germinal vesicle?

It is the nucleus of the cell; a somewhat large, transparent, and well-defined body set somewhat eccentrically in the vitellus—the yolk of the egg.

What is the germinative spot?

The nucleolus of the cell. In addition to the nearly transparent

fluid which the nucleus contains, there is a small dark, almost opaque spot, the germinal spot of the ovum.

Do all the Graafian follicles develop ova ?

No. From puberty to the menopause the formation of new Graafian follicles is continuous, and a very great number are produced, but many do not develop ova, and so waste away without going through the changes described.

Describe the Fallopian tubes.

These tubes are about $3\frac{1}{2}$ inches in length, and extend from the fundus of the uterus laterally on each side. The calibre of the tubes gradually narrows from without inward, until at the uterus the opening is very minute. The external covering is peritoneum, but the lining is of mucous membrane, having ciliated epithelium. The outer end of the Fallopian tube is free and fringed—the fimbriated extremity.

What is the function of the fimbriated end of the Fallopian tube ?

To grasp the ovary during sexual excitement and prevent the escape of an ovum which may extrude—the “morsus diaboli.”

What is the use of the ciliated epithelium ?

To carry the ovum to the uterus. This is also accomplished by the action of the circular and longitudinal muscular fibres.

Describe the uterus.

It is a somewhat pear-shaped organ, and is about 3 in. in length, its wider part being about 2 in. wide and the cervix 1 in. It is described as consisting of a fundus, body, and cervix. The body unites the fundus with the cervix, which extends into the vagina.

What structures compose the uterus ?

It is covered over nearly all of its external surface by (1) peritoneum. Its bulk is made up of unstriped (2) muscle, which occurs in longitudinal and circular bundles and layers. This muscular tissue increases enormously during pregnancy, and by its strength helps to extrude the foetus. The lining is of (3) mucous membrane, which is formed in its superficial layer of ciliated columnar epithelium. In the mucous membrane of the cervix are a number of follicles which secrete a viscid, tenacious mucus, by which the os uteri is frequently found to be plugged.

Describe the vagina.

It is a membranous canal about 5 in. long, extending from the uterus to the external genitals. It is lined with mucous membrane, which in the ordinary contracted state is thrown into folds, its anterior and posterior walls being in contact. There is considerable erectile tissue in the mucous membrane. At the orifice of the vagina externally is a sphincter which only partially contracts it, and besides this there are longitudinal and transverse unstriped muscle-fibres in the submucous tissue. The outlet of the vagina is sometimes also partially closed in the virgin by the hymen, a fold of mucous membrane.

What are the external organs of generation ?

The external organs of generation are not immediately connected with the function of reproduction, and may be enumerated as the labia majora and minora, clitoris, and the meatus urinarius.

What are the organs of generation in the male ?

The two *testicles* which produce the seminal fluid, and the *vas deferens*, or duct leading from each to the *seminal vesicles*, where the secretion is stored until it is discharged through the *penis*.

What is the structure of the testicles ?

Each testicle is made up of a dense connective-tissue framework and a secreting portion. The connective-tissue stroma, tunica albuginea, surrounds the outside of the organ, and sends incomplete partitions into the central portion of the organ, dividing it into a number of communicating cavities. In these cavities are winding tubules which constitute the secreting portion of the organ. These tubules inosculate in a sort of mesh (*reti testis*), and finally all unite in the epididymis. The secreting tubules are called the *seminiferous tubules*.

How do the seminiferous tubules secrete the spermatic fluid ?

Each tubule has, in the active organ, a limiting membrane, upon which are a number of layers of flattened cells. Internal to these are *seminal cells* in two or more layers. The seminal cells contain nuclei which are capable of division, so that each nucleus may develop several new nuclei. The nuclei are the spermatoblasts, or cells from which the spermatozoa originate. The cells before the division of the nuclei resemble the ordinary cuboid epithelium, and it is in the superficial layers (*i. e.* toward the lumen of the tubuli) that this function of the cells takes place.

How is the seminal fluid conveyed from the testis?

The seminiferous tubules all converge toward the epididymis, a tortuous tubule which is lined with mucous membrane, and lies beside the testis in a long, convoluted mass which may be unravelled, and is found to be about 20 feet long. This empties its contents, or rather continues on, in the *vas deferens*, which conveys the semen to the seminal vesicles. During this passage the mucous membrane adds a viscid mucous secretion in which the spermatozoa are liberated and, so to speak, diluted.

What is the appearance of the spermatozoa?

In the seminiferous tubules the developing spermatozoa may be seen with the heads all united in the cells from which they arise, the tails projecting brush-like into the cavity of the tube. But they are soon separated. They then consist of a head and a tail (Fig. 55). In length they are about $\frac{1}{5000}$ to $\frac{1}{4000}$ of an inch. The head is somewhat elliptical and the tail gradually tapers. In other animals than man the size and form vary from those of man, though in a general way they conform.

What action of the spermatozoon permits it to enter the uterus and Fallopian tube?

There is a very active vibratory motion of the tail of the spermatozoon, which allows it quite free motion in a fluid medium. It is by this swimming motion, in which it may be compared to a tadpole, that the seminal cells are able to reach the ovum against the action of the cilia in the uterus and Fallopian tube.

Is a single spermatozoon sufficient to fecundate an ovum?

It probably is. There have been more than one seen in an impregnated ovum, but it is probable that only one enters into the formation of the male pronucleus, the rest remaining inactive.

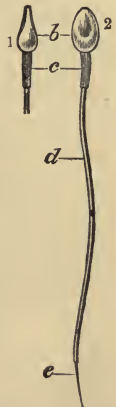
Where is the ovum impregnated?

In the Fallopian tube.

What leads us to the conclusion that the egg is fecundated in the Fallopian tube?

(1) The spermatozoa are found there. (2) Before the ovum

FIG. 55.



Human Spermatozoon:
1, in profile;
2, viewed on the flat; b, head; c, middle-piece; d, tail; e, end-piece of the tail.

leaves the Fallopian tube it has gained an albuminous coat which would probably be impervious to the spermatozoa. (3) The unimpregnated egg degenerates before it enters the uterus, and is then probably incapable of impregnation.

What are the seminal vesicles?

They are tubules which join the vasa deferentia, and lie upon the base of the bladder, emptying into the urethra by the ejaculatory ducts through the prostate gland. In structure the vesiculæ seminales are convoluted. They are lined by a mucous membrane which is convoluted and folded so as to give it a sacculated appearance.

What is the prostate gland?

It is a gland lying at the base of the bladder and surrounding the urethra at its beginning. It has the general structure of the glandular organs, and in addition a considerable amount of muscular tissue. Its acini empty into ducts which empty in the urethra. Its function is not exactly known.

Describe the penis.

It consists of three more or less cylindrical bodies of erectile tissue enclosed in fibrous sheaths. The two corpora cavernosa lie above, and receive between them, below, the corpus spongiosum, in which the urethra is contained. The glans penis is continuous with the corpus spongiosum. The covering of the penis is of loose skin, but over the glans penis and lining the prepuce it resembles mucous membrane. In this region there is an abundant subcutaneous nerve-plexus, and the Pacinian bodies are quite numerous, so that it is possessed of acute sensibility.

Describe the urethra.

It extends from the bladder through the corpus spongiosum to the end of the penis. It is lined with mucous membrane, and is furnished in its deeper layers with numerous muscular fibres. There are a number of ducts of glands opening into it whose function is not fully understood, though their secretion is supposed to be added to that of the seminal vesicles to make up the semen.

How is the erectile tissue of the penis arranged?

The erectile tissue consists of a system of distensible veins lying in the interstices of a fibrous connective tissue. The erector

penis muscle by its contraction compresses the veins of the organ, and the veins become turgid with blood. The arteries enter the structure of the erectile tissue along the pubic bone, and are not pressed upon by the contraction of the muscle.

What is menstruation ?

It is a periodical change which accompanies ovulation in women.

Is menstruation dependent upon the ripening and discharge of an ovum ?

No. The phenomena of menstruation may occur without the rupture of a Graafian follicle, and, on the other hand, ovulation may occur in amenorrhœic women. As a rule, however, the two processes are simultaneous, and the discharge of an ovum occurs during the period.

What is the character of the menstrual discharge ?

It is a thin, bloody fluid of a dark color and having a peculiar odor. It consists of blood, epithelium, and mucus from the uterus and vagina, together with the decidua menstrualis. The blood does not clot.

What is the decidua menstrualis ?

It is a membrane developed by the uterine mucous membrane for the purpose of furnishing a site for the implantation and growth of an impregnated ovum. It occurs entirely within the body of the organ, and does not extend into the cervix. If impregnation does not occur, the decidua menstrualis breaks down and leaves its vessels bleeding.

Why does not the menstrual blood clot ?

Probably because of its mixture with the mucus of the uterus and vagina.

What is the duration of menstrual life ?

Usually in temperate climates from fourteen or fifteen to forty-five or fifty years of age. The periods recur regularly at intervals of about four weeks, but the occurrence of pregnancy causes a cessation which lasts through lactation, with occasional exceptions.

What is the corpus luteum ?

After the escape of an ovum there is an effusion of blood into the cavity of the Graafian follicle. The clot which follows is disposed of by the same retrogressive processes which extravasated

blood may undergo in any part of the body. The serum is absorbed, the cells disintegrate, and the coloring matter is in part taken up by the tissues and in part crystallizes or takes up other constituents, and presents variations of coloring. Hand in hand with these changes in the blood go important changes in the surrounding tissues. The epithelial cells which are left behind proliferate and form a soft yellowish, very vascular tissue, which presently undergoes fatty degeneration. This yellow mass surrounding and enclosing the remains of the extravasated blood constitutes the corpus luteum, and as it disappears its place is occupied by a dense, firm connective-tissue cicatrix, which may be pigmented.

How does the corpus luteum behave during pregnancy?

It then does not degenerate and disappear rapidly as after menstruation, but continues fully as large for several months, and at the end of pregnancy still remains as a clearly marked body. This is shown in the following table from Dalton:

	<i>Corpus Luteum of Menstruation.</i>	<i>Corpus Luteum of Pregnancy (Dalton).</i>
At the end of three weeks.	$\frac{3}{4}$ in. in diameter; central clot reddish; convoluted wall pale.	Larger; convoluted wall bright yellow; clot still reddish.
One month.	Smaller; convoluted wall bright yellow; clot still reddish.	
Two months.	Reduced to the condition of an insignificant cicatrix.	$\frac{7}{8}$ in. in diameter; convoluted wall bright yellow; clot perfectly decolorized.
Four months.	Absent or unnoticeable.	Size about as at two months; clot pale and fibrinous; convoluted wall dull yellow.
Six months.	Absent.	Still as large as at the end of the second month. Clot fibrinous. Convoluted wall paler.
Nine months.	Absent.	$\frac{1}{2}$ in. in diameter; central clot converted into a radiating cicatrix; external wall tolerably thick and convoluted, but without any bright yellow color.

At what time is the ovum liable to impregnation?

Probably most so immediately before the menstrual period, but

owing to the fact that both the female and male elements may remain in the genital passages of the female for some days in a healthy condition, it is difficult to fix the time of actual impregnation of the ovum.

What facts lead to the supposition that impregnation takes place most commonly before menstruation?

(1) It is probable that in most instances the rupture of the Graafian follicle occurs very early in the menstrual period. (2) The uterus is in the most favorable condition to sustain the fecund ovum at that time, because of the presence of the decidua menstrualis. (3) Among the Jews, a remarkably prolific race, coitus is prohibited by the religious law for a week after menstruation.

DEVELOPMENT.

What changes occur in the ovum before impregnation?

The ovum, after leaving the ovary and while still in the Fallopian tube, undergoes certain changes. These changes are mostly confined to the nucleus or germinal vesicle. *The germinal spot or nucleolus disappears*, and the outline of the vesicle becomes indistinct, elongated so that it has a spindle-shape. While in this condition the spindle develops two or three vesicles, which collectively form the *female pronucleus*.

What changes in the ovum follow impregnation?

The head of a spermatozoon penetrates the vitelline membrane and enters the vitellus, where it remains surrounded by protoplasm. This is the *male pronucleus*. The male and female pronuclei soon join, and then follows a process of growth by the splitting up of the nuclei to form new nucleated protoplasmic cells.

What is this splitting-up process called?

Segmentation. The first cell which is formed by the union of the male and female pronuclei is called the blastosphere or primitive segmentation germ.

What other change then occurs?

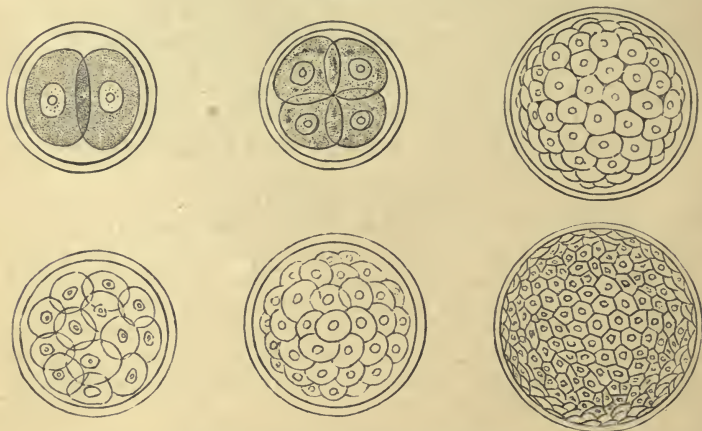
The ovum receives an addition of a layer of clear albuminous material while still in the Fallopian tube, which adds considerably to its bulk. This corresponds to the white of a hen's egg.

What is segmentation of the vitellus?

The next change which occurs in the impregnated egg is the split-

ting up of the vitellus or yelk, first in halves, then in quarters, and so on until the vitellus becomes a mass of minute granular-looking nucleated cells (Fig. 56). The segmentation of the nucleus continues with the corresponding change in the yelk.

FIG. 56.



Segmentation of the Vitellus in the Impregnated Egg of the Rabbit (Coste).

Where does this change occur?

In the Fallopian tube. The human ovum probably remains in the Fallopian tube for eight or ten days before reaching the uterus, and while there does not materially alter its appearance. Barring the fact that there is added to its circumference an albuminous layer, it is unchanged in external looks.

What is the germinal membrane?

The outer layers of vitelline cells after segmentation are closely packed and resemble polygonal epithelial cells, and in fact form a sort of lining to the zona pellucida, holding the liquid of the vitellus in a central cavity. This lining is the germinal membrane or blastoderm.

Why does the segmentation of the vitellus take place?

This is not known, nor is it understood how it occurs, but it follows the union of the male and female elements of generation only.

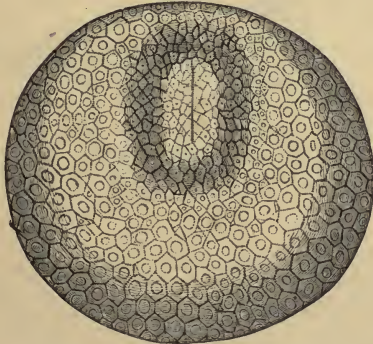
How are changes in the developing ovum commonly studied?

In the development of the egg of the common fowl. This is on account of the accuracy with which the time of development may be watched, and the convenience to the observer of such simple growth by incubation compared with uterine growth. The processes of development are not materially different.

What changes occur in the blastoderm?

There appears at one point an opaque streak (Fig. 57), which is

FIG. 57.



• Diagram of the Area Germinativa, showing the primitive trace and area pellucida.

found to be due to the proliferation of the cells of the blastoderm. This is the *primitive trace*, and it grows in length and breadth.

What changes occur in the arrangement of the cells of the blastoderm at this time?

They separate into three layers, the *epiblast*, *mesoblast*, and *hypoblast* (Fig. 58); and along the axis of the primitive trace a groove is formed which is destined to become the cerebro-spinal axis. This is the *primitive groove*.

What changes occur in the zona pellucida at the entrance of the ovum into the uterus?

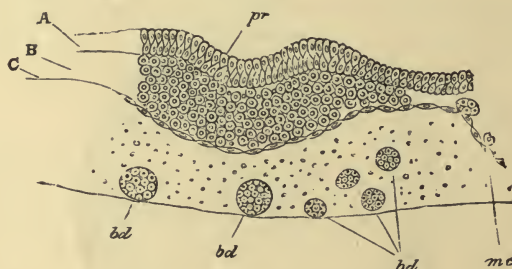
The surface of the ovum becomes shaggy with the appearance of

numerous villi, which are probably derived from the epiblast. This is known now as the *chorion*.

What changes occur in the uterus?

The decidua menstrualis has been mentioned as specially suitable for the reception of the ovum. But if impregnation occur, it is not called by this name, as menstruation does not occur. It is then known as the *decidua vera*. It consists of a thick, succulent

FIG. 58.



Section of a Blastoderm at right angles to the long axis of the embryo, near its middle, after eight hours' incubation (from Foster and Balfour): A, epiblast formed of two layers of cells; B, mesoblast thickened below the primitive groove; C, hypoblast, formed of one layer of flattened cells; *pr*, primitive groove; *bd*, formative cells in the so-called segmentation or subgerminal cavity. (The line of separation between the epiblast and mesoblast below the primitive groove is too strongly marked in the figure.)

mucous membrane caused by the proliferation of the subepithelial cells. Into this decidua the ovum falls, and its shaggy chorion implants its villi in the crypts of the mucous membrane. The decidua soon envelops it, and the portion which is reflected over the ovum is known as the decidua reflexa.

What important changes now begin to occur in the blastoderm?

The blastoderm, which is increasing in area from the rapid proliferation of cells, folds at each end transversely and at the sides longitudinally. These folds are of great importance, for it is in this way that the contour of the body is outlined, and if it were not for them the blastoderm would continue to develop as a flat surface. The transverse folds are at each end, and are known as

the *head* and *tail* folds. The longitudinal folds define the outlines of the body.

How does the medullary groove develop?

The ridges in the epiblast on either side continue to thicken, and finally coalesce at the back, leaving a lining of cells within a tube. These cells develop the cerebro-spinal axis and follow the curves of the blastoderm longitudinally. The head fold gradually becomes constricted, and becomes the neck. Meanwhile the mesoblast has developed a number of processes, which become a primitive spinal column. It is to be noticed that the enclosure of the spinal canal in this way is by a folding process, and all through the process of development this peculiarity is very marked.

What is the mode of the formation of the pleuro-peritoneal cavity?

The mesoblast divides near the median line, and one part of the split mesoblast adheres to the epiblast, while the remainder joins the hypoblast. The former is known as the somatopleure, and the latter as the splanchnopleure, and the included space becomes the pleuro-peritoneal cavity, which subsequently divides to form pleura, pericardium, and peritoneum.

What structures are developed from the epiblast?

The epidermis and appendages of the skin, the great nervous centres, the nerves, and the principal portions of organs of special sense—eye, ear, nose.

What does the hypoblast develop?

The epithelial elements, including the glands and the mucous membranes lining the alimentary and pulmonary tracts.

What does the mesoblast develop?

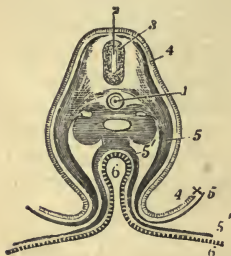
The bones, muscles, fasciæ, and connective tissues of the body. It also develops the vascular system. It must be remembered that very early in the embryonal life this tissue divides to join with the epiblast and hypoblast, and we can therefore understand how it may develop the muscular structures of the intestinal canal.

What is the destiny of the splanchnopleure?

The splanchnopleure (5', Fig. 59) folds in over the remainder of the ovum, and so walls off, so to speak, a portion of the vitellus which communicates freely with the rest of the yolk-sac. Later on, after

the formation of the amnion, the yelk-sac forms a blind pouch which is lined by hypoblast and has an external covering of mesoblast (Fig. 59), as is shown at 6 in the accompanying cut. The upper 6 is in the primitive gut, which derives its epithelial elements from the hypoblast and its muscular and serous coverings from the mesoblast.

FIG. 59.



Transverse Sections through the Embryo Chick, before and some time after the closure of the medullary canal, to show the upward and downward inflections of the blastoderm (after Remak) on the third day in the lumbar region: 1, notochord in its sheath; 2, medullary canal, now closed in; 3, section of the medullary substance of the spinal cord; 4, corneous layer; 5, somatopleure of the mesoblast; 5', splanchnopleure (one figure is placed in the pleuro-peritoneal cavity); 6, layers of hypoblast in the intestines, spreading also over the yelk; 4×5, part of the fold of the amnion formed by epiblast and somatopleure.

What is the yelk-sac then called?

The umbilical vesicle.

What is the function of the umbilical vesicle?

From it the embryo derives its sustenance in the earlier stages. Early in the development blood-vessels begin to form, and they ramify over the surface of the umbilical vesicle and help to absorb its contents.

What is the amnion?

While the one portion of the split mesoblast (splanchnopleure) unites with the hypoblast to form the splanchnoblast and alimentary organs, the outer layer (somatopleure) and epiblast are united to form the skin and walls of the body as the somatoblast. The somatoblast now folds in about the embryo. It must be remembered, however, that the entire globe of the ovum is lined with these cells, and that in folding in this way the cells are in

a measure raised away from the wall of the ovum. The layers of the somatoblast fold back until they meet and unite behind the embryo, and in this way form a layer of membrane which lines the ovum and another layer which encloses the embryo (Fig. 60). This latter layer forms the amnion. (This is better understood by reference to the cuts.)

What is the use of the amnion?

It covers the embryo in the early stages very closely, but soon becomes distended with a pale watery fluid, and serves to float

the foetus and give it equal mechanical support on all sides. The outer layer of the amnion becomes very thin and adheres to the chorion.

FIG. 60.



FIG. 61.



FIG. 60.—Diagram of the Fecundated Egg, farther advanced: *a*, umbilical vesicle; *b*, amniotic cavity; *c*, allantois.

FIG. 61.—Diagram of the Fecundated Egg, with allantois nearly complete: *a*, inner lamina of amniotic fold; *b*, outer lamina of amniotic fold; *c*, point where the amniotic folds come in contact. The allantois is seen penetrating between the inner and outer laminae of the amniotic folds.

What is the composition of the amniotic fluid?

It is water containing small quantities of albumin and urea.

What is the allantois?

During the development of the amnion from the somatoblast a change has occurred in the splanchnoblast. From the inferior extremity of the included portion of the yolk-sac, which is to become intestine, there has budded a small mass which develops rapidly, following the outline of the amnion (see Figs. 60, 61, 62), and grows fast to its chorion layer. This structure, *the allantois*, soon becomes very vascular and carries its blood-vessels to the chorion.

What is the function of the allantois?

It nourishes the growing embryo. The chorion has already become tufted with capillary loops, and has established a connection with the decidua of maternal growth. As the vessels of the allantois communicate more and more with the chorion, the embryo derives more of its sustenance

FIG. 62.



Diagram of the Fecundated Egg, with the allantois fully formed: *a*, umbilical vesicle; *b*, amnion; *c*, allantois.

from the mother, and the remains of the yelk-sac (umbilical vesicle) dwindle as the need is less and the substance is consumed. (See Figs. 60, 61, and 62.)

What structures in the body are derived from the beginning of the allantois?

The urinary bladder and the urachus, an impervious cord extending from the bladder to the umbilicus.

How is the chorion made up?

It consists of several layers which fuse into one vascular membrane. The allantois, the outer layer of the amnion, and the vitelline membrane are united in the chorion. As the embryo develops the vessels of the chorion become thinner on the side toward the uterine cavity, and more distinct on the opposite side. This change continues as the embryo increases, until the *placenta* is formed by the branching of the embryonic vessels and the increase of the decidua at the corresponding point.

What changes occur in the uterus in developing the placenta?

In the deeper part of the mucous membrane of the uterus at the implantation of the chorion there are hollowed out spaces or sinuses in the tissues which communicate both with a maternal vein and an artery; that is, special arrangements are made for the rapid circulation of a large amount of blood in the uterine mucous membrane at the placental site. At the same time, the glandular structures of the uterine mucous membrane are increased, and the follicles run deeply into the thick and succulent tissues.

How do the villi of the chorion become implanted in the uterine wall?

The villi dip down and develop new tufts of capillaries in the deepened crypts of mucous membrane, so that the tufts of capillaries of the chorion may be said to resemble in a way a glove filled with foetal blood dipping into a vessel filled with maternal blood.

Does the blood of mother and foetus actually come in contact?

No. There are four layers of cells between the maternal and the foetal blood: 1, wall of chorion capillary; 2, cells of chorion; 3, cells of uterine follicle; and 4, wall of the uterine sinus.

Do the tissues of the placenta maintain an exchange of material?

Yes. The mother's blood furnishes to the foetal blood food and

oxygen, and in turn removes the carbonic acid and excrementitious material which the foetus must lose; that is, the placental circulation supplies the place taken in after-life by the alimentary and the respiratory tracts.

Does the entire placenta leave the uterus immediately after the birth of the child?

No. The foetal part is almost all, excepting some of the capillary tufts which are torn off, discharged in the after-birth; but the decidua is not entirely disposed of in this way, the portions remaining being in part absorbed and in part found in the lochia which occur for a few days after the birth.

What is the appearance of the placenta?

It appears as a thick, cake-like disk of vascular tissue. Its maternal and foetal portions are so intermingled that they cannot be separated. In size it covers about one-third of the uterine wall.

At what period of gestation is the placenta formed?

At about the third month of pregnancy. Before that time the chorion is covered by the decidua reflexa and nourishes the embryo, but as the placenta becomes more developed other parts of the chorion atrophy.

From what tissues is the umbilical cord formed?

From the vascular allantois, which carries the arteries and vein. It has, however, an external coating of the amnion and the shrivelled umbilical vesicle and its duct (Fig. 63). How this occurs will readily be seen by reference to the accompanying cut.

Why do the maternal vessels not bleed excessively after the placenta is torn from its implantation?

There is, of course, a loss of the blood contained in the uterine sinuses, but the general balance of the circulation is not disturbed at childbirth. The reason for this is the oblique entrance of the placental

FIG. 63.



Human Embryo and its Envelopes at the End of the Third Month, showing the enlargement of the amnion.

vessels. They enter the sinuses at an angle, and are therefore compressed by the muscular tissue of the uterus in its contracted state.

How is the vertebral column developed ?

Early in the development of an embryo there is formed beneath the medullary groove in the mesoblast a thin thread of soft cartilage known as the *chorda dorsalis*, or *notochord*. This soon becomes included in a sort of fibrous sheath, and is the primary axis from which the bodies of the vertebræ are developed. On either side of the notochord are developed small centres which subsequently split. These are the *protovertebræ*. From these are developed the vertebræ and the heads of the ribs by the *inner layer*, and by the *outer* (or posterior) *layer* the muscles and skin of the back, the epidermis being derived from the epiblast.

How do the protovertebræ form the vertebræ ?

It is not by direct ossification of the protovertebræ, but they separate in such a way that adjacent protovertebræ each contribute half to the vertebra formed. That is, two protovertebræ form parts of two vertebræ, one above and the other below, and also form a whole vertebra by their adjacent portions.

How is the cranium developed ?

By the prolongation of the epiblast over the protovertebræ to the cephalic end of the embryo. Here it develops three segments, corresponding to the three primary vesicles which are the forerunners of the brain. These centres of ossification are at the base of the skull, the bones of the vertex being developed from membranes.

How is the face formed in the embryo ?

At the head fold of the embryo the mesoblast does not split into two parts, as below, but folds in from the side, covered without and within by the epiblast and hypoblast. These folds develop certain clefts from which the face is derived, the mesoblast furnishing the bone and muscle structures, and the epiblast the epidermis, while the hypoblast gives the mucous membrane which lines its cavities.

Describe the cleft which develops the face.

Immediately below the anterior cranial vesicle there occurs on either side a cleft in the lateral fold of the embryo extending to the vesicle for the eye. In the space of this cleft there is devel-

oped a sort of secondary cleavage of the parts, which by the rapid growth of the parts included between the clefts resembles a budding (Fig. 64). It is by the growth of these buds or processes that the outline of the face is formed. From each side sprouts the superior maxillary process, and the processes unite in the median line, meeting the nasal or intermaxillary process from the upper border of the cleft. The portion below is cut off by a branchial cleft, which, becoming the mandibular process, forms the lower jaw.

FIG. 64.



Development during First Month.

What defects in the face are due to faulty development of these processes?

When the processes do not unite as they should, various defects occur; most common are those about the mouth, cleft palate and hare-lip, by failure of the superior maxillary processes to unite or by failure of the intermaxillary process to unite with the maxillary.

Do the other branchial clefts persist in later life?

No. They become closed as they accomplish their use in developing certain organs: as pathological factors, however, we are often convinced of their non-union or of flaws in their development, cysts and tumors of various kinds and certain fistulæ being attributable to this cause.

How are the extremities developed?

They develop as buds from the somatoblast early in foetal life, and the formation of the joints and lesser details of structure are gradually worked out. At about the third month the separation of the fingers and division of the extremity into joints is about completed. The arm develops somewhat in advance of the leg, and grows rather more rapidly in the earlier period of intra-uterine life.

What two forms of circulation are found in the embryo?

The earliest is the *vitelline* circulation, in which vessels from the foetus pass over the yolk-sac and carry nutrition to the growing organism. There is formed a *placental* circulation, in which the maternal blood furnishes the elements of food.

What is the vascular area (area vasculosa) of the foetus?

Among the earliest changes in the blastoderm, occurring in the second week, of impregnation, is the formation of blood-vessels and blood-corpuscles. This occurs by the proliferation of certain branched cells of the mesoblast, and these cells form a closed system of branching capillaries, their nuclei acquiring a red color and becoming the blood-corpuscles. This area is external to but connected with the embryo.

How is the heart formed?

At about this time certain cells of the visceral layer of the mesoblast (splanchnopleure) develop a tube upon each side of the body, and these two tubes soon coalesce to form a single tube (Fig. 65), which receives two veins at its lower end and gives off two arteries at its upper. This is the primitive heart, and pulsations begin in it very feebly almost as soon as there is a trace of the originating cells. This structure soon develops a muscular tissue, and a circulating fluid which shortly presents the character of blood.

FIG. 65.



FIG. 66.

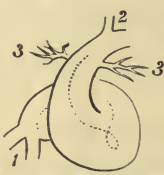


FIG. 65.—Earliest Form of the Foetal Heart: 1, venous extremity; 2, arterial extremity.

FIG. 66.—Foetal Heart bent upon itself: 1, venous extremity; 2, arterial extremity.

What is the next important change in the form of the heart?

It bends itself so as to assume a U-shape, which shortly is twisted in such manner that the arterial end of the heart crosses in front of the venous (Fig. 66), and the loop suggests the outline of the ventricles. The vitelline

circulation in the human ovum is not very long-lived, for the chorion is early formed and the stock of nutrient protoplasm in the yolk-sac is very small.

What further modifications does the heart undergo?

The septum between the ventricles grows, and separates the heart into two divisions; and at about the same time the auricles are developed and the valves become well marked. These changes occur in the fourth to the eighth week of embryonic life.

Describe the vitelline circulation.

The area vasculosa extends all about the blastoderm upon the

surface of the vitellus, and as the folds of the embryo occur the vessels are brought to enter the body through the space at which the vitellus is shut in to form the primitive gut. There are then two arteries and two veins, which are known as the omphalo-mesenteric vessels. This form of circulation soon gives way to the placental, and the vessels passing to the umbilical vesicle waste, those belonging to that portion of the original vitelline cavity which forms the intestine, becoming the mesenteric vessels.

What are the prominent features of the placental circulation?

(1) In the arterial circulation some conditions of the heart and great vessels are necessary to modify the pulmonary circulation before the air enters the lungs at birth. (2) In the circulation of the liver the veins present modifications to allow for the return placental circulation.

Where do the arteries to the placenta arise?

They follow the allantois in its growth. Springing from the internal iliac artery of each side, two arteries pass up the umbilical cord and break into the branches in the placenta which terminate in capillary tufts.

How does the blood return to the body from the placenta?

By the umbilical vein it is taken to the liver, where part of it circulates through the liver-capillaries in the same manner as the blood from the portal vein, the remainder passing through the *ductus venosus*.

What is the ductus venosus?

It is a large vein which appears at the under surface of the liver, and returns a large part of the blood from the umbilical vein directly to the inferior vena cava, without circulation in the capillaries of the organ.

How does the ductus venosus appear in adult life?

Soon after birth the umbilical vein and ductus venosus become an impervious cord extending from the navel to the liver: the

FIG. 67.



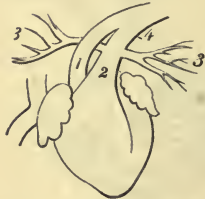
Diagram of the Embryo and its Vessels, showing the circulation of the umbilical vesicle, and also that of the allantois, beginning to be formed.

former becomes the round ligament of the liver, while the ductus venosus remains as a small fibrous cord.

What is the course of the foetal blood through the heart?

It enters the right auricle, and is thence sent in part to the right ventricle, and in part to the left auricle, through the foramen ovale, an opening left in the development of the auricular septum. The blood which enters the left ventricle from the left auricle is forced out through the aorta (Fig. 68). The right ventricle, however, sends but a small part of its blood to the lungs, but delivers it through the *ductus arteriosus* to the aorta. The blood is in this way sent into the systemic circulation, a part going to the placenta through the internal iliac, hypogastric, and umbilical arteries.

FIG. 68.



Foetal Heart still farther developed: 1, aorta; 2, pulmonary artery; 3, 3, pulmonary branches; 4, ductus arteriosus.

What effect has the Eustachian valve upon the blood-stream in the foetal heart?

It throws the blood from the inferior vena cava through the foramen ovale into the left auricle. In this way the stream of blood coming from the superior vena cava crosses that from the inferior cava on entering the heart, inasmuch as the blood from the superior vena cava enters the right ventricle.

What effect does this division of the blood-stream have upon the distribution of the blood in the foetus?

The circulation of the blood is made more perfect, for the branches of the aorta given off to the head and upper extremities distribute blood from the inferior vena cava; while the ductus arteriosus, carrying the blood from the superior cava and right ventricle, enters the aorta in such a way that most of its blood is sent to the lower extremities and abdominal organs and umbilical arteries. In this way the deoxidized blood is sent back to the placenta for the renewal of its oxygen.

How does this result in the development of the lower extremities?

They develop less rapidly than the upper. There are probably two reasons for this: 1, the blood is less well aerated and less nutritious; 2, the internal iliac arteries, giving off the umbilical arteries, probably divert a considerable portion of the blood-supply of the external iliacs which go to the lower extremities.

What changes occur in the circulation after the birth of the foetus?

The respiratory centre in the medulla, which has been quiescent because it has been sufficiently well supplied with oxygen, is awakened as soon as the connection with the uterine sinuses is interrupted. As soon as the supply of oxygen sinks to a certain point, an impulse of inspiration is generated, and the infant breathes and the lungs assume a condition of partial expansion. With the diminished resistance in the expanded lungs the amount of blood in the pulmonary circulation increases, and the amount passing through the ductus arteriosus diminishes, and this is soon obliterated. At the same time, the blood returning to the left auricle increases in quantity, and the intra-auricular pressure is greater; then, too, the inferior vena cava sends less blood, for the ductus venosus no longer carries the blood from the placental circulation, and therefore the foramen ovale is not used, and is soon closed by the adhesion of its valve-like curtain. Thus we have the adult circulation established in the place of the foetal in consequence of the respiratory movements.

How is the spinal cord formed?

It will be remembered that the medullary canal encloses in its cavity cells from the epiblast which line it. These cells by proliferation and differentiation develop nerve-cells and nerve-fibres, the latter at first not medullated. The cells also gradually close in upon the medullary canal, and form a central canal lined with epithelium, a layer of nerve-cells (gray matter), and a layer of nerve-fibres (white matter).

How do we account for the obliquity of the spinal nerves and for the cauda equina?

When the spinal cord first appears it fills the entire spinal canal, but at the time of birth the cord has apparently not grown so rapidly as the vertebral column, for it then ends at the third lumbar vertebra, and in the adult it ends at the first. Thus we are able to explain the apparent origin of the spinal nerves above their point of exit from the canal, and the increasing obliquity of the nerves from above down, until finally, in the tuft of vertical nerves below the extremity of the cord, we see the extreme degree of this peculiarity.

How do the spinal nerves develop?

They are formed from cells arising from the epiblast lining the

medullary groove. Before the closure of this groove to form the medullary canal an offshoot from the epiblast may be observed, which is the source of the posterior nerve-roots; and they become attached to the cord as it develops. The anterior roots spring from the cord after it has developed fibres. The two roots then join and the nerve grows out into the mesoblast.

Are the cranial nerves similarly derived?

In much the same way the cranial nerves arise primarily, except the nerves of special sense. In function the motor nerves seem to form a sort of anterior root for the sensory, so that they may be arranged in pairs corresponding to the anterior and posterior roots of the spinal nerves; and it does not seem entirely fanciful to regard their development as somewhat similar, thus:

Third, fourth, sixth, and seventh motor, fifth sensory. Twelfth motor, ninth sensory. Eleventh motor, tenth sensory.

How does the earliest rudimentary brain appear?

The medullary canal is widened from the very beginning at its anterior end, and very early develops three vesicles, which are shown diagrammatically in Fig. 69. These vesicles, with their lining of epiblast, are the primitive brain.

FIG. 69.



How does the anterior cerebral vesicle become changed?

This vesicle is destined to become the third ventricle of the brain, and from its anterior surface are developed two protrusions which expand to form the hemispheres of the brain; thus, this vesicle is early divided into two parts, the fore-brain or prosencephalon, and the inter-brain or thalamencephalon.

What is the middle primary vesicle called?

The mesencephalon. It corresponds to the aqueduct of Sylvius.

How is the posterior vesicle altered?

This is destined to become the fourth ventricle, and by a similar protrusion it develops a second portion, which becomes the cerebellum. These divisions of the posterior cerebral vesicle are

Formation of the Cerebro-spinal Axis: 1, vesicle of the hemisphere; 2, vesicle of the tubercula quadrigemina; 3, vesicle of the medulla oblongata.

known as the epencephalon, and the after-brain, or metencephalon.

What parts of the brain do these five vesicles respectively originate?

I. Anterior primary vesicle.	1. Prosencephalon.	{ Cerebral hemispheres, corpora striata, corpus callosum, fornix, lateral ventricles, olfactory bulb.
	2. Thalamencephalon.	{ Thalami optici, third ventricle, optic nerve.
II. Middle primary vesicle.	3. Mesencephalon.	{ Corpora quadrigemina, crura cerebri, aqueduct of Sylvius.
	4. Epencephalon.	{ Cerebellum, pons Varolii, anterior part of fourth ventricle.
III. Posterior primary vesicle.	5. Metencephalon.	{ Medulla oblongata, fourth ventricle, auditory nerve.

What is the primary optic vesicle?

About as soon as the cerebral vesicles are distinctly formed a budding of two projections—one from either side of the anterior vesicle—occurs. These are the primary optic vesicles. They are formed before the vesicles which make the hemispheres (prosencephalon). The projections approach the external epiblast, and at that period consist of a finger-like process having a globular dilatation at the end. This subsequently forms the optic nerve and the retina.

How is the crystalline lens formed?

Opposite the optic vesicle the superficial epiblast is depressed and forms a sort of pit, forcing the optic vesicle to fold in upon itself. The follicle of epiblast is shut off at the surface, and a ball of its substance left in the cup of the infolded optic vesicle. This ball forms the rudimentary lens, and the anterior layer of the vesicle is the retina.

How are the other tissues of the eye evolved?

The muscular and vascular structures, as well as the connective tissue and humors, are derived from the mesoblast, which in part enfolds the ocular vesicle and in part enters it between the lens

and the edge of the cup-like depression. The cornea is of later formation, and is derived from the epiblast of the skin.

How is the auditory apparatus developed ?

Very early in the life of an embryo there is a depression on either side of the head which passes through the same process as that mentioned for the crystalline lens and for the germinal epithelium in the formation of ova. The mass of epiblast thus separated forms the epithelium of the labyrinth and vestibule, the surrounding mesoblast furnishing the bony and muscular structures. The auditory nerve is developed with other cranial nerves, and grows in to its end-organs from its central origin.

How is the olfactory apparatus derived ?

In a similar way to the internal ear and the lens. The nasal fossa is primarily a depression in the superficial epiblast, which widens and deepens and receives the nerve-filaments from the olfactory lobe. This lobe is originally a bud from the prosencephalon. The primary olfactory depression continues to widen until it opens into the mouth, and is again shut off by the growth of the branchial arch, which forms the superior maxilla. The nose is similarly derived from the mesial and lateral nasal processes.

Describe the method of the development of the alimentary canal.

As has already been explained, the primitive alimentary canal is formed from the involution of the splanchnopleure, and is really a portion of the yolk-sac partially shut off from the rest. It is at each end a blind pouch which follows the head and tail folds. The portions have received the names *fore-gut* and *hind-gut* as they occupy one or other of these folds.

How does the fore-gut become changed ?

It joins with the mouth-cavity by the folding back of the epiblast in the formation of the branchial arches, and from it are formed the pharynx, œsophagus, and stomach.

How does the hind-gut approach the surface ?

By a similar involution of the epiblast the anus and about half of the rectum are formed, into which the hind-gut opens to complete the alimentary tract.

What deformities in the new-born depend upon the defective accomplishment of these changes ?

The œsophagus is sometimes impervious at birth, and the rectum

or anus may also be imperforate. This is caused by the non-union of the segments developed from the epiblast with those developed from the hypoblast.

How are the glands of the alimentary tract developed?

(1) The *salivary glands* are developed from the epiblast lining the oral cavity. They appear primarily as a simple tube which develops branches, about which the alveoli are formed.

(2) The *pancreas* is similarly developed from the hypoblast of the fore-gut.

(3) The *liver* is primarily a protrusion of the hypoblast of the fore-gut, which appears as soon as the blood-vessels begin to show themselves. The omphalo-mesenteric vein, from the umbilical vesicle, breaks up into a capillary plexus, and the hepatic cells develop about it.

How are the lungs derived?

They first appear as a bud at the junction of pharynx and œsophagus which soon forms a separate tube (the trachea). The cells from the hypoblast extend into the surrounding mesoblast, and it is from this structure that all of the tissue of the lungs, except its mucous membrane, are formed.

What is the Wolffian body?

It is a rounded body which is first seen as early as the third week as an increase of the cells of the mesoblast, just inside of its division into parietal and visceral layers, on each side of the vertebral column. It is soon seen to consist of three parts, from which are derived the genito-urinary organs. The largest of these in early embryonic life retains the name *Wolffian body*, and is not a permanent organ; a second, lying just above, develops the internal organs of generation; while the third, lying behind the Wolffian body, is the rudimentary kidney.

What is the function of the Wolffian body?

The Wolffian body proper—that is, after its division into three sections—is a temporary kidney. At first this is a large glandular body, resembling the kidney in structure, which possesses a duct leading to and opening into the hind-gut. At about the sixth week of foetal life the kidney begins to grow and the temporary organ to atrophy. As this occurs a duct for the kidney (the ureter) is developed from the Wolffian duct. The use of the

organs seems to be that of temporary kidneys, but by the end of the third month they have been replaced by the permanent organs, and have almost entirely disappeared.

How do the testicle and ovary originate?

The body (germinal epithelium) which appears on the inner side of the Wolffian body is the nucleus of the future testicle or ovary, while from the outer side there springs a duct (Müller's) which passes down to the cloaca or lower end of the hind-gut. At first it is impossible to determine the sex of the foetus.

How do the remaining genital organs of the female develop?

The ducts of Müller join to form the uterus and vagina, while the ununited portions remain as the Fallopian tubes. The Wolffian ducts, which also spring from the Wolffian bodies, are rudimentary in the female and appear as a part of the parovarium.

How do the remaining male organs of generation develop?

The *Wolffian ducts* become convoluted tubules, and each is attached to the testis as the epididymis. Müller's duct is rudimentary in the male, and is only found as the sinus pocularis and the hydatids of Morgagni.

How are the external genitals formed?

In both sexes in early foetal life the external genitals are alike, consisting of a body resembling a penis with a fold of skin at either side. *In the female* this body becomes proportionately smaller, and appears as the clitoris, the two lateral masses becoming the labia majora. *In the male* a groove on the under surface unites at its borders to form the urethra, while the scrotum is formed from the folds of skin at the side. This differentiated condition may persist in adult life, and has been mistaken for hermaphroditism.

PARTURITION.

How is the foetus extruded from the uterus?

In part by the contraction of the uterine muscles, and in part by the pressure exerted by the abdominal walls. The uterine contractions are the first to appear, and it is not until the foetus enters the vagina that the abdominal muscles are brought into play.

What causes excite the uterine contractions?

As to this no satisfactory answer has been given. Why the

uterus should contain the growing embryo for months, and then be suddenly thrown into action to expel it, cannot be explained.

What is the nature of the act of parturition?

It is a reflex action depending upon a centre in the lumbar spinal cord. Whence the stimuli are derived which excite the reflex is unknown, but probably from the organ itself.

What is the character of the uterine contractions?

They are rhythmical in character, and may be compared to the contractions of the heart-muscle. Each "pain" begins feebly, gradually intensifies until it reaches a maximum, and then gradually declines until it entirely dies away, to be succeeded by another similar contraction and pause. This rhythmical action continues until the uterine contents are expelled, and then the organ enters into a condition of tonic contraction.

APPENDIX.

TABLE OF THE DEVELOPMENT OF AN EMBRYO.

(Modified from Gray's *Anatomy*.)

1st Week.—Ovum in Fallopian tube. Segmentation of vitellus.

2d Week.—Ovum in uterine decidua. Chorion. Formation of blastoderm and division of mesoderm. Heart and medullary groove. Amnion and umbilical vesicle formed. Allantois.

3d Week.—Head and tail flexures. Closure of medullary canal, and formation of primary cerebral vesicles and ocular and auditory vesicles. Branchial arches. Wolffian bodies. Limbs.

4th Week.—Limbs increased. Anal opening. Interventricular septum begins. Ant. spinal nerve-roots. Olfactory fossæ. Lungs. Pleuræ.

5th Week.—Allantois vascular. Trace of feet and hands. Müller's duct and genital gland.

6th Week.—Umbilical vesicle disused. Branchial clefts close. Post-spinal nerve-roots. Membranes of the nervous centres. Bladder. Kidneys. Tongue. Larynx.

7th Week.—Muscles perceptible. Many centres of ossification appear.

8th Week.—Joints appear in extremities; fingers and toes separate. Crystalline lens. Salivary glands. Spleen. Interventricular septum complete. Sympathetic nerves.

9th Week.—Distinction between ovary and testicle. Genital furrow. Pericardium.

3d Month.—Formation of placenta. External genitals separate from anus. Eyelids, hairs, and nails. Duct of Wolffian body joins testicle.

4th Month.—Middle-ear bones. Tympanum and labyrinth. Scrotum and prepuce.

5th Month.—Germs of teeth. Hair- and sweat-glands. Brunner's glands. Uterus and vagina distinctly separate.

6th Month.—Papillæ of skin. Sebaceous glands. Peyer's patches. Free border of nails.

7th Month.—Cerebral convolutions. Pupillary membrane disappears.

8th Month.—Descent of testis.

9th Month.—Opening of eyelids. Ossification of cochlea.

CHEMICAL TESTS USED COMMONLY IN PHYSIOLOGICAL ANALYSIS.

FOR PROTEIDS :

Nitric Acid coagulates all except peptones.

Heat.—All are coagulated by boiling, except peptones.

Xanthoproteic Reaction.—A solution boiled with strong nitric acid becomes yellow: the color is deepened by the addition of ammonia.

Biuret Reaction.—With a trace of copper sulphate and an excess of potassium or sodium hydrate they give a purple reaction.

Millon's Reaction.—With a solution of metallic mercury in strong nitric acid (Millon's reagent) they give a white or pinkish reaction, and the color becomes more pink on boiling.

FOR STARCH:

Iodine Reaction.—Add to a solution of starch a small quantity of tincture of iodine, and a blue reaction results. The color disappears on heating and returns on cooling.

Glycogen.—Same test gives reddish reaction, port-wine color, which disappears on heating and returns on cooling.

FOR SUGAR (GLUCOSE):

Moore's Test.—Boil solution of sugar with an excess of potassium hydrate, brown color-reaction.

Trommer's Test.—Add to solution a sufficient amount of potassium hydrate to render it quite strongly alkaline. Then add a solution of copper sulphate, drop by drop, until a distinct blue tinge is visible. Heat, and the presence of sugar is shown by appearance of red, yellow, or orange color-reaction.

Fehling's Test Solution.—An alkaline copper solution by which a quantitative test may be made. The solution is somewhat unstable, and is for this reason to be tested by boiling before using. The strength of the solution is such that 1 cubic cm. (15 minims) will be exactly decolorized by $\frac{1}{200}$ of a gramme (.075 grains) of glucose. This test is very delicate, and is quite commonly used for urinary examinations to detect glycosuria.

The Fermentation Test.—If a small quantity of yeast be added to a sugar solution, the fungus of the yeast (*saccharomyces*) will cause the sugar to be decomposed into carbonic acid and alcohol. If the process be continued until the sugar is entirely broken up, the amount of carbonic acid evolved indicates the proportion of sugar present.

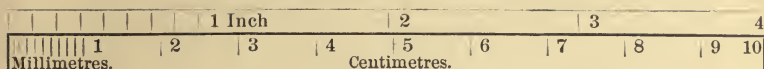
FOR BILE SALTS:

Pettenkofer's Test.—Upon the addition of sulphuric acid to a solution of bile-salts in water there is a precipitation of the salts, which are redissolved by a further addition of the acid. If a drop of a solution of cane-sugar be added, a deep cherry color is developed.

FOR BILE PIGMENTS:

Gmelin's Test.—Add a small quantity of nitroso-nitric acid to a solution of the bile-pigments, and a play of colors results, beginning with green and changing to blue, violet, red, and yellow. This is seen best on a white background; therefore a plate is often used for this test.

METRIC SYSTEM.



The area of the figure within the heavy lines is that of a square decimetre. A cube one of whose sides is this area is a cubic decimetre or *litre*. A litre of water at the temperature of 4° C. weighs a *kilogramme*.

A litre is 1.76 *pint*; a pint is 0.568 of a litre.

The smaller figures in dotted lines represent the areas of a square centimetre and of a square inch.

A cubic centimetre of water at 4° C. weighs a *gramme*.

Square
Centi-
metre.

Square Inch.

Metre = $39\frac{2}{5}$ inches.

Centimetre = $\frac{2}{5}$ inch.

Millimetre = $\frac{1}{25}$ inch.

Micromillimetre = $\frac{1}{25000}$ inch.

Gramme = $15\frac{1}{2}$ grains.

Centigramme = $\frac{3}{20}$ grain.

Milligramme = $\frac{3}{2000}$ grain.

Kilogramme = 2.2 pounds.

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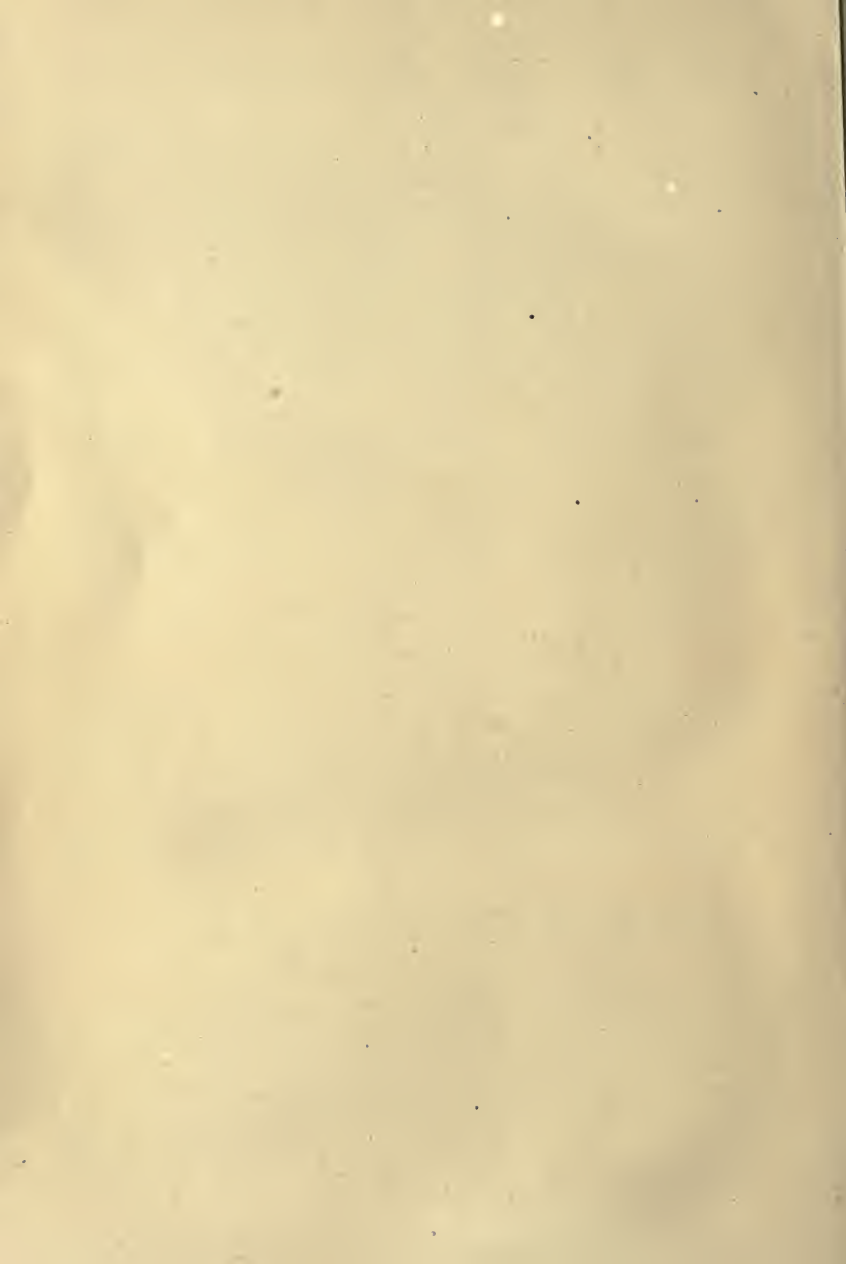
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